§27. Effect of Potential on Energy Transport

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In toroidal helical plasmas, the electric field has a significant effect on helically trapped particle orbits whose guiding center motion is expressed by $d\theta/dt=V_{perp}\cos\theta/r+\omega_{ExB}+\omega_{grad\text{-}B}$, where θ, V_{perp}, ω_{ExB} and ω_B represent the poloidal angle, the toroidal drift velocity, the rotation angular velocities due to ExB and grad-B drifts, respectively. Here, the definitions are $V_{perp}=\varepsilon_t W/qBr$, $\omega_{ExB}=E/Br$, $\omega_{grad\text{-}B}=\varepsilon_h W/qB\,r^2$, with W and q being the energy and the charge, respectively. If the resonance condition $\omega_{ExB}+\omega_{grad\text{-}B}=0$ (or $W = e\phi/\varepsilon_h$) is satisfied, the helically trapped particles run away from the plasma owing to the toroidal drift. Then a loss cone will spread over the plasma.

Using an analytical formula, a loss cone of deeply trapped ions for the NBI plasma using the observed negative potential profile is shown in Fig. 1a. The loss cone plays a role when the helically trapped particles can accomplish their one-turn orbits poloidally without a collision. The condition is expressed as $\omega_{grad\text{-}B} > \nu/\varepsilon_h$, and the critical energy W_{rot} to satisfy this condition is plotted in Fig. 1a, assuming $\varepsilon_h=\varepsilon_{ha}(r/a)^2$.

When the NBI is injected into this plasma, the beam energy to heat ions and electrons equally is represented by W_{eq}=15Te. Above this energy (=15 Te), the beam particles heat selectively electrons, preserving the pitch angle. On the other hand, the tangentially injected beam particles experience pitch angle scatterings in the region below this energy, transferring their energy to ions. Simultaneously, the beam particles begin to enter into the loss cone below this energy.

The neutral beam energy of the CHS is about 35 keV. The energy transfer from injected beams to bulk ions occurs in the regime between the upper loss cone boundary and the energy of W_{eq}(=15Te). For the bulk ions, the ion temperature is below the lower loss cone boundary, therefore, the bulk ions are confined by the rotation due to ExB motion. If the potential becomes sufficiently negative for the loss cone region to be located above the energy of W_{eq}, the ion heating efficiency will be improved since the pitch angle scatterings occur below the loss cone region.

We can also demonstrate a loss cone region for deeply trapped electrons for the low density ECH plasma with a positive potential. It is shown in Fig. 1b that the loss cone region above the energy of W_{rot} exists only in the outside (x>0). The critical energy W_{rot} for electrons is higher than that for ions since the collision frequency is larger for the same energy.

Thus, the electron heated up by the wave on the outside of torus will easily enter into the loss cone. As for ions, the loss cone region in this positive potential is localized only in an outside periphery of the plasma. This fact suggests that a scenario to realize a hot ion mode is possible if a positive potential profile can be created in an NBI-heated plasma with an effective use of ECH.

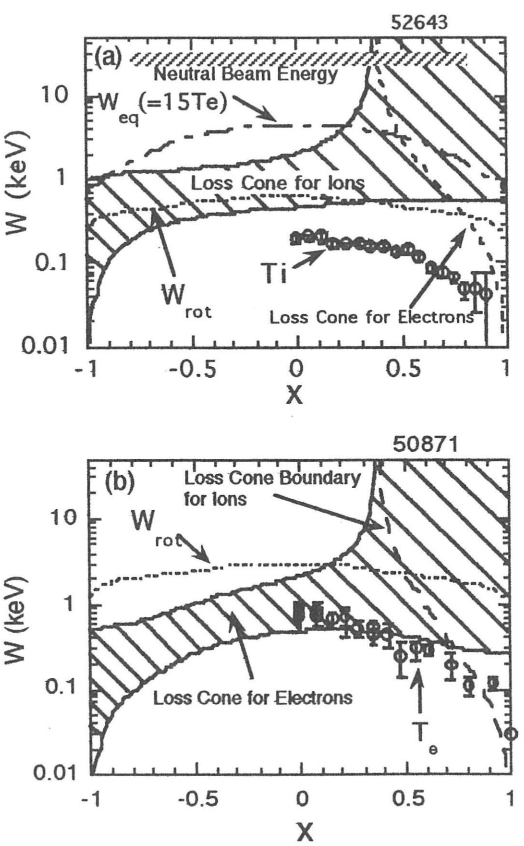

Fig.1.(a) Evaluated loss cones for an NBI plasma. (b) Evaluated loss cones for an ECH plasma.