§60. Parameter Dependence of the Resonant Loss

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It is known for helical devices that the particle with a specific energy is lost by cancellation of the ∇B drift and the $E \times B$ drift resulting from the electric field E. [1] This phenomenon occurs at the negative radial electric field. The reason why we are interested in the resonant loss is that we can find it from the dip in the high-energy particle spectra measured by the neutral particle analyzer. (We can find only the decreasing flux in the loss cone, therefore it is very difficult to distinguish the effect of the loss cone from other effects).

Since it is assumed that the dip observed near 5keV is the resonant loss, the comparison of the spectrum for various plasma parameters is performed at this energy. Fig. 1 shows the density dependence in the plasma whose conditions are similar. From the results of charge exchange spectroscopy, the electric field in LHD is positive at densities less than about $1 \times 10^{19} m^{-3}$ and negative at larger. The critical density depends on the magnetic axis position and the plasma temperature. The parameter d on the vertical axis in Fig. 1 is given by Eq. (1) as the degree of the dip near 5keV.[2]

$$d = \log(\text{Real Flux}) - \log(\text{Expected Flux}), \quad (1)$$

where *'Expected Flux'* is the flux at the dip point, obtained from the polynomial fitted spectrum excluding the flux at the dip. The magnitude of the negative electric field around $\rho = 0.9$ slightly increases when the density becomes high. This means two things. One is that the resonant energy, at which the ∇B drift compensates the $E \times B$ drift, increases. Another is that if we consider the same energy, the region with the equivalent potential is shifted inward where the background neutral is poor (back ground neutral density decays in the plasma center), that is, the neutral flux at that energy decreases. The extension of the dip at high density can be explained by this effect. Figure 2 shows the dependence of d on the electron temperature in three different density region cases because the electric fields are strongly dependent on the density. When the electron temperature increases, the radial electric field becomes positive. Therefore the dip depth (absolute value of d) decreases as the temperature increase. In the low-density region, the correlation between the temperature and the d looks weak since the electric field is sensitive against the density. The dependence of d on the magnetic axis position is also investigated. Plasma parameters also change as a function of the magnetic axis position or the magnetic field strength in many cases. We choose similar plasma parameter shots. When the magnetic axis is shifted outward, the particle loss increases because the helical ripple increases. The increase of the dip depth indicates the effect. If the magnetic axis is shifted outside, although it will become stable in the magnetic hydrodynamics (MHD), from the viewpoint of particle confinement, it is not desirable theoretically. The dependence of the d against the magnetic field strength is also investigated. The increase of the dip depth at the lower magnetic field indicates bad particle confinement. Finally, the dependence of the d on the pitch angle is studied as shown. According to the experimental results, the dependence of the pitch angle is not so remarkable. The typical time scale of the pitch angle scattering T_D^{ii} is

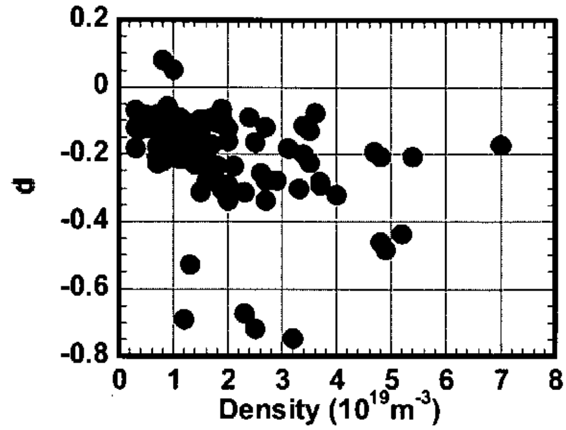

Fig. 1 The density dependence of the dip depth.

$$T_D^{ii} = 4.53 \times 10^{-3} \frac{A_i^{1/2} T_i^{3/2}}{Z_i^4 (n_i / 10^{20}) \ln \Lambda} [\text{sec}], \quad (2)$$

where A_i, T_i, Z_i, n_i and $\ln\Lambda$ are the mass number, the ion temperature, the ion density and the Coulomb logarithm, respectively. T_D^{ii} is a few milliseconds for the actual LHD plasma although the NPA detection duration is several tens of milliseconds. Since pitch angle scattering is dominant and reaches equilibrium at the energy of 5 keV, the number of particles with lower pitch angle also decrease if the particle with higher pitch angle are lost.

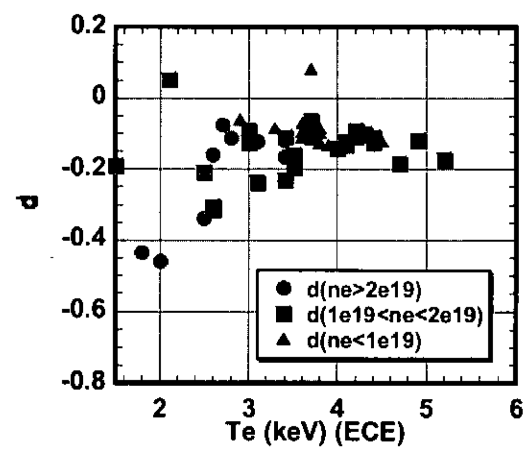

Fig. 2. The temperature dependence of the dip depth.

[1] K. Hanatani, *et al.*, Nucl. Fusion 25 (1985) p.259.

[2]T.Ozaki, et al, Plasma Phys.and Fus. Res. SERIES.(to be published)