§22. Computer Analysis of the Cyclotron Resonance Heating in a LHD-type Magnetic Configuration

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We have analyzed the relation between a cyclotron resonance magnetic configuration and heating efficiency. It is shown in the trapped orbit diagram TPOD [1] of the LHD, that (Type-I: Fig.1) cyclotron resonance heating focused on the magnetic axis of horizontally-long cross section of magnetic surface ($\phi = 2n\pi/10, n = 0, 1, \cdots$), is more efficient than (Type-II; Fig.2) cyclotron resonance heating focused on the magnetic axis of vertically-long cross section of magnetic surface ($\phi = (2n+1)\pi/10, n = 0, 1, \cdots$). In the Type-I configuration, rf heated particles become mirror trapped particles. On the other hand, in the Type-II configuration, rf heated particles become chaotic orbit particles.

We have developed a new scheme to calculate an rf heating efficiency using energy change of collision-less rf heated particles $E_0^n(t)(n = 1, \cdots, N)$. Since the collision effect of plasma particles is small compared with acceleration by the rf electric field, we treat the slowing down process by electrons as a perturbation process. Heating power $< P_e >$ for electrons reduces to the following relation,

$$< P_e >= \sum_{n=1}^{N} \frac{V_{\mathrm{res}} N_e}{N \tau_s T_{\mathrm{cmp}}} \int_0^{T_{\mathrm{cmp}}} \mathrm{d}t' \times \left\{ E_0^n(t') - \frac{1}{\tau_s} \int_0^{t'} \exp\left(-\frac{t'-t''}{\tau_s} \right) E_0^n(t'') \mathrm{d}t'' \right\} \quad (1)$$

where T_{cmp}, V_{res}, and τ_s are the cutoff time for collision-less trajectory, volume of the cyclotron resonance region in one helical pitch, and slowing down time, respectively.

Using the relation(1), we have estimated the ICRF heating efficiency as a function of plasma density, RF electric field is assumed to be $E_{\mathrm{rf}} = 10\,\mathrm{kV/m}$. Plasma temperature is calculated by a relaxation scheme.

1) Tsuguhiro WATANABE, Alpha-Particle Confinement Control of the Geodesic Winding of LHD-Type Fusion Reactors, (PFR, 8, 2403072 (2013)).

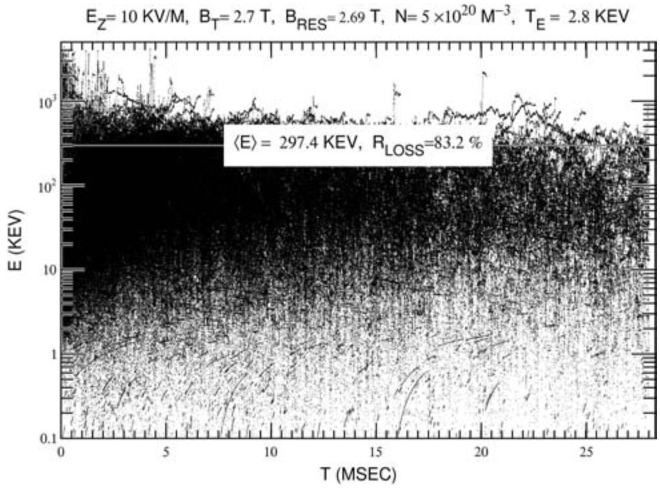

Fig. 1: Cyclotron resonance heating focused on the magnetic axis of horizontally long cross section of magnetic surface($\phi = 3\pi/5$).

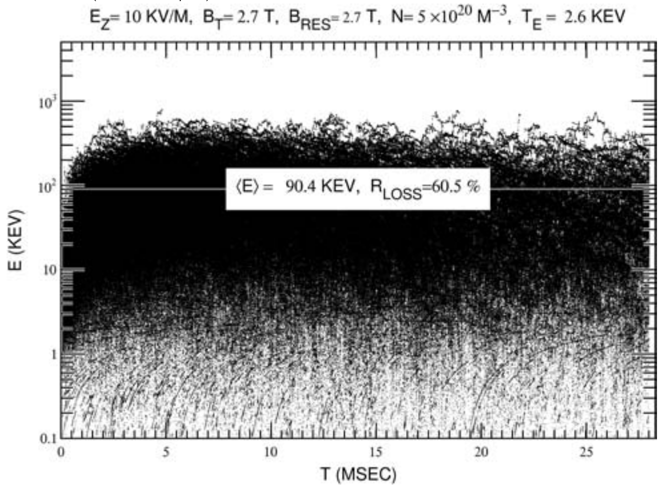

Fig. 2: Cyclotron resonance heating focused on on the magnetic axis of vertically long cross section of magnetic surface($\phi = \pi/10$).

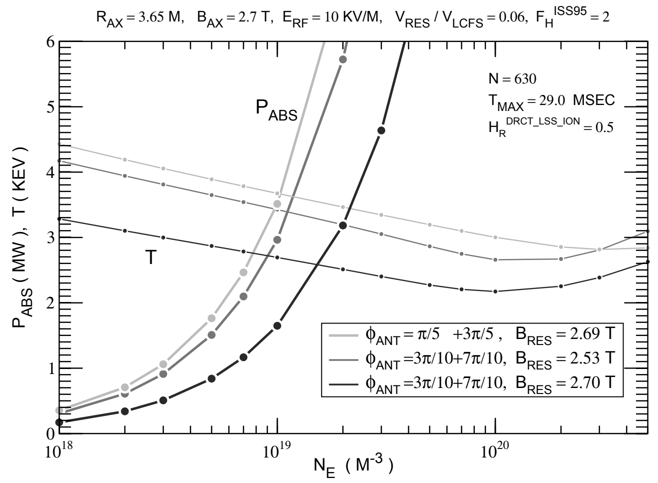

Fig. 3: ICRF heating of the LHD using 2 antenna units.