§ 7. Resonance Heating in Front of the ICRF Antenna

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The ICRF heating experiment was carried out in the 6th cycle campaign of LHD. The plasma density began to rise at the end of the long pulse ICRF discharges, and the discharge stopped 150 seconds later. It is thought that this density increase was caused by some local temperature increase inside of the vacuum vessel. The CCD camera recorded a red-glowing stria of specific diverter plate during the ICRF experiment(Fig.3). This phenomenon was analyzed by the particle orbits calculation for the ICRF heating of LHD.

The magnetic configuration, in which the highest heating efficiency has been achieved, has two (upper and lower) ion cyclotron resonance layers in front of the antenna (see Fig.1). Then we have calculated orbits of protons whose initial positions are placed at the cyclotron resonance layers. Protons are considered as just after the ionizing, and initial energy of them are assumed to be very low (1 or 100 eV). Initial pitch angles are distributed uniformly between $3\pi/8$ to $5\pi/8$. RF field $\boldsymbol{E}(\boldsymbol{x}, t)$ are assumed to be near field localized in the front of the 3.5L-ICRF antenna.

$$\boldsymbol{E} = \left[0, 0, E_0 \sin(\omega t - M\varphi) \exp\left\{-256(\varphi - \pi/2)^4\right\}\right] ,$$

where toroidal mode number M is assumed to be 0 or 40, $E_0 = 20$ kV/m and $\omega/2\pi = 38$ MHz (resonance field B_{res} is 2.5 T). Magnetic field is assumed to be $R_{ax} = 3.6$ m and $B_{ax} = 2.75$T. Particle orbits are traced until they reach to vacuum vessel wall.

Figure 1 shows the particle Poincare plot in the meridian plane where the ICRF antenna is placed. There are two types of accelerated protons. One group is accelerated protons mainly in perpendicular direction of magnetic field and are trapped in weak magnetic field region ($B < B_{res}$). Another group is protons considerably accelerated in the magnetic field direction due to the finite $k_{\|}$ effect of ICRF wave, and are extended into the core plasma regions.

The lifetime and the final energy of protons lost on vacuum vessel wall are plotted in Fig.2.

It is confirmed that particles heated at upper resonance layers run off to the specific red-glowing diverter tile (the standing tile at 2.5L port) as shown in Fig.3.

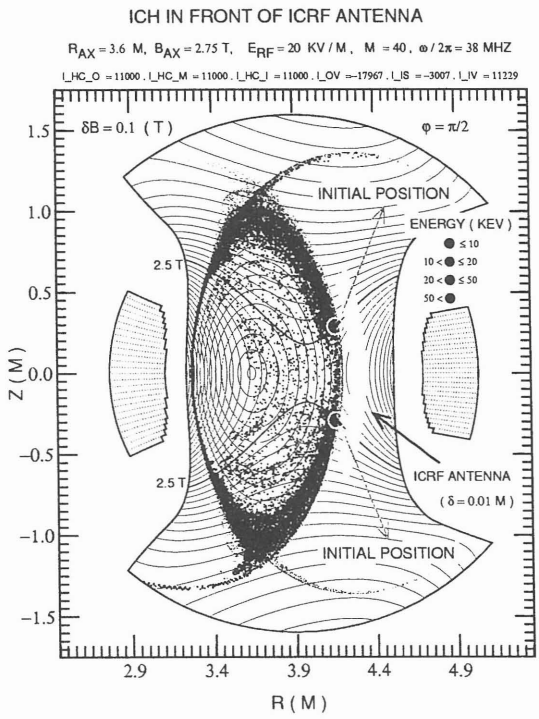

Fig.1: Poincare plot of ICEF heated protons. The magnetic surface structure is shown by the dots in the azure.

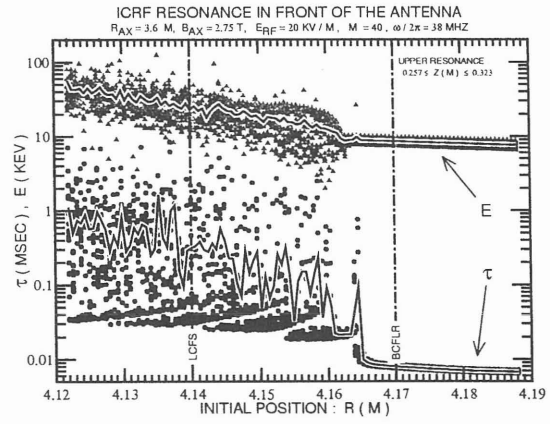

Fig.2: Lifetime and final energy of ICRF accelerated protons. The position of the last closed flux surface (LCFS) and boundary of chaotic filed line region (BCFLR) is also shown. Average values are shown by solid kinked lines.

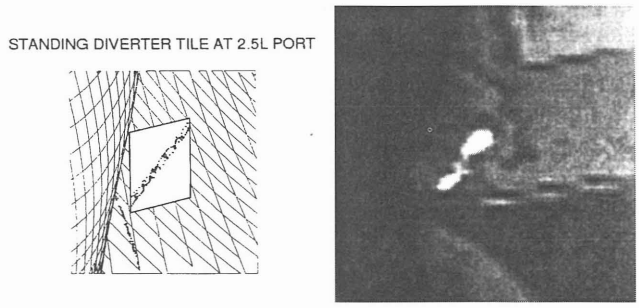

Fig.3: Bird's-eye view of diverter chart of ICRF heated particles from the CCD camera position. An actual CCD image is also shown (Shot number is #36392 and ICRF is on).