§14. High Energy Tail Production and Confinement in ICRF Minority Heating

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In LHD, the best performance on ICRF heating was obtained by the minority-ion heating mode[1]. High energetic ions tail was produced by this mode, and the behavior of the particles gives us a lot of information on the confinement ability of LHD. The ions heated by ICRF have large pitch angle to the confinement magnetic field, therefore those particles behave as the helically trapped particles.

In minority-ion heating mode, the high-energy tail component was frequently observed when the cyclotron resonance layers were located at the magnetic axis or near the saddle point on the mod-B contours. Especially at the magnetic axis, the tail component extremely enlarged and

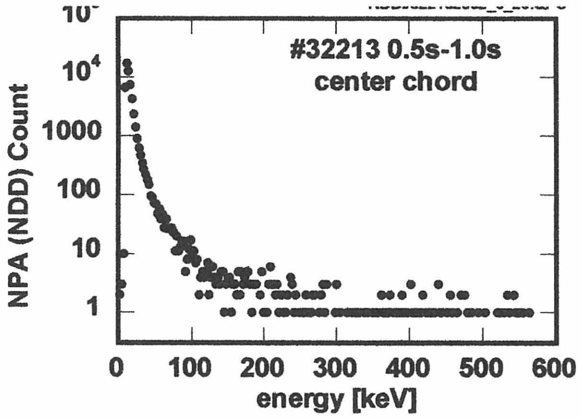

Fig.1 Energy distribution of minority protons when the ion cyclotron resonance located at the magnetic axis (B=2.5T, Rax=3.6m, 38.47MHz, He/H:minority, ne=$0.5\times10^{19}m^{-3}$, P_{ICRF}=800kW, Natural Diamond Detector)

the particles having the energy of over 500keV was observed as shown in Fig.1. These results show that LHD has enough ability to confine the high-energy particles having large pitch angle.

Theoretical analysis shows that the performance of inward shifted axis configuration of Rax=3.6m/3.53m is much better than with the standard axis of Rax=3.75m. Experimentally same results have been reported in many papers. However the comparison on the high-energy ion confinement was not yet clear.

To find the clear experimental result, ICRF power modulation and the measurement of the Silicon-NPA detectors were tested. Figure 2 shows the time traces of the charge exchange particle flux of the center chord Silicon-NPA detector. Six different energy channels are shown. Each energy channels from 52 to 78 keV are modulated and their phase shifts from the power modulation are gradually changed. On the higher energy channels, phase delays are large as compared with the lower energy channels. The phase delays analyzed by the numerical process are shown in Fig.3. Phase differences from the applied RF power are shown on the energy range of 30 to 110 keV.

Physically the phase delay means that the tail formation needs a finite time and this growth time should be appeared as the phase delay. If the particle confinement time is short as compared with the growth time, phase delay should be decreased. Therefore in case of the worse particle confinement, the phase delay was small.

In Fig.3, phase delays of the flux in the case of three different radii of the magnetic axis (Rax) are shown. The

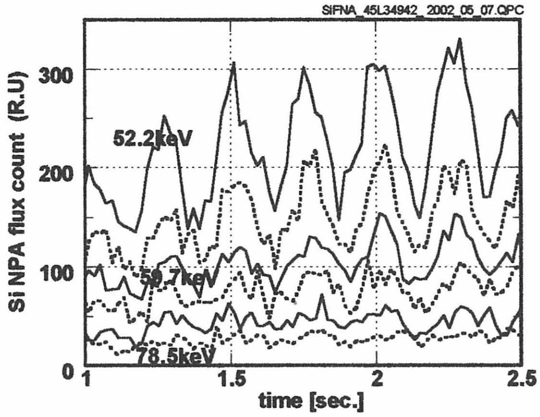

Fig.2. Time traces of Silicon NPA detector at different slices of energy range on the magnetic axis chord.
(Energy range from top; 52.2,55.9,59.7,63.5,71,78.5keV, Rax=3.6m, B=2.75T, Resonance: saddle point)

data of Rax=3.6m is obtained in the normal inward shifted mode and 3.53m is the neo-classically optimized configuration. The Rax=3.75m is the standard axis position. There is a large difference between the three cases. This phase difference can be explained by the analysis of time dependent Fokker-Planck analysis[2] which newly includes the particle loss term. Analysis shows that the fast particle loss decreases the phase delays and the behavior is consistent with the results of Fig.3. (see in this annual report by K.Saito)

This modulation technique clearly shows the difference of fast particle confinement property. The results shows that Rax=3.6m is better than other two cases.

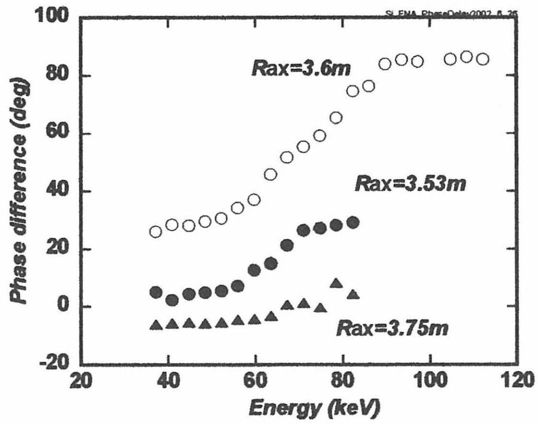

Fig.3 Fast particle flux phase delay from ICRF pulse. Large phase difference indicates better high energy particle confinement.

References
1) Mutoh, T. et al., Phys. Rev. Letts. **85** (2000) 4530
2) Saito, K. et al., Plasma Phys. Control. Fusion **44** (2002) 103