§ 6. High Energetic Particle Limiter of LHD at Low Magnetic Field Intensity

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The magnetic field of LHD is generated with a set of right-handed helical coils. Therefore, lines of force of a magnetic surface of LHD wind around the magnetic axis in right-handed way. On the other hand, the direction of the $\boldsymbol{B} \times \nabla B$ drift of an ion is left-handed direction, except just under the helical coils. Then, an ion that runs in magnetic field direction ($v_{\parallel} > 0$), winds around the magnetic axis more slowly than lines of force and can keep more strong adiabaticity for particle motion. Therefore, the drift surface of the ion with $v_{\parallel} > 0$ extends over outside of the outermost magnetic surface and the drift surface of the ion with $v_{\parallel} < 0$ is limited inside of the outermost magnetic surface. The difference of this drift surfaces is small for the usual magnetic field strength level ($B_{ax} = 2 \sim 3$ T).

However, magnetic field is reduced even to $1/5 \sim 1/6$ ($B_{ax} = 0.5 \sim 0.6$ T) level of the normal operating condition, in the high beta plasma experiment in LHD. At this time, the drift surface of the high-energy particle with $v_{\parallel} > 0$ extends over the outermost magnetic surface widely. Fig.1 shows a numerical example of the almost outermost drift surface of E=180 keV protons ($R_{ax} = 3.6$ m and $B_{ax} = 0.5$T). Therefore, devices such as armor tiles for NBI, ICRF antennas and inner vacuum vessel wall, those are placed near to the outermost magnetic surface, act as a limiter for high energetic particle, when magnetic field is drastically reduced.

It was confirmed by the computer analysis that the strong light emission of the side-protector on the 7.5L-ICRF antenna, which was stuck out 2cm compared with the maximum backspace position ($\delta = 0.05$m) in the 6th cycle LHD campaign) and the sublimation and erosion of the edge of the armor tile of NBI-3 (found after 5th cycle LHD campaign) are caused by the interference with the high energetic co-injection NBI particles. Fig.2 shows the numerical results of limiter effect of armor tile of NBI-3 at $B_{ax} = 0.5$ T on 180 KeV NBI particles. It was confirmed numerically also that these devices do not interfere with the drift surface of 180keV NBI particles, if the magnetic field on the magnetic axis go over 0.8T ($B_{ax} \gtrsim 0.8$T).

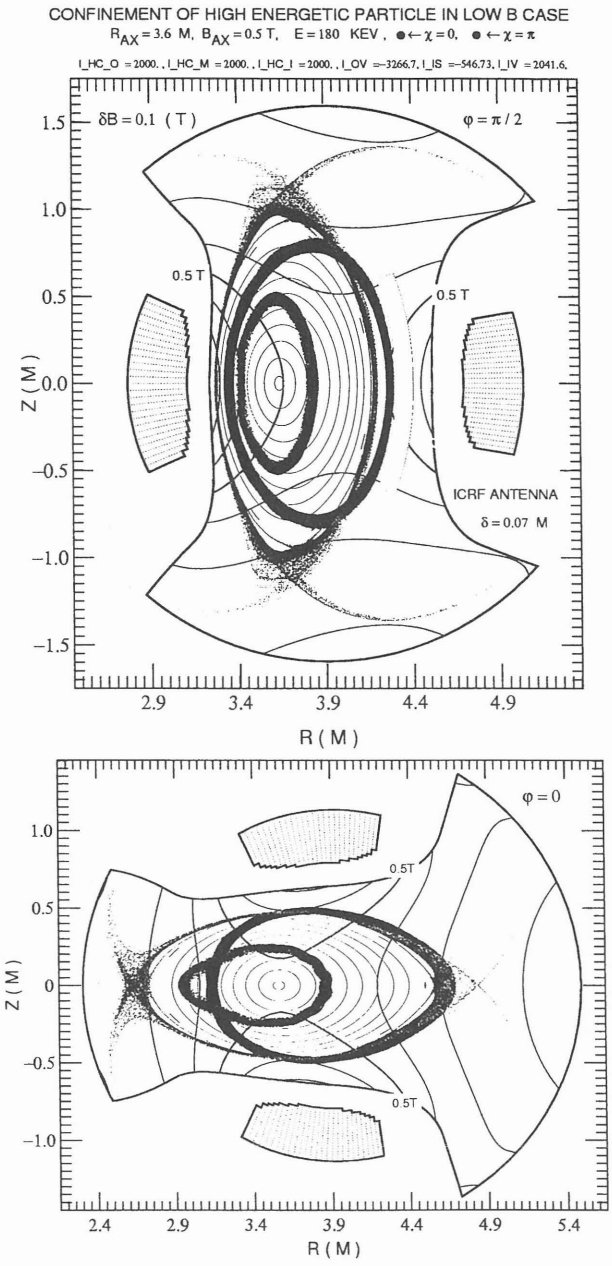

Fig.1: Poincare plots of almost outermost drift surface of 180keV NBI particles ($B_{ax} = 0.5$T). The red (green) points represent the 180 keV co-beam (counter beam) particles. The magnetic surface structure are shown by the dots in the azure.

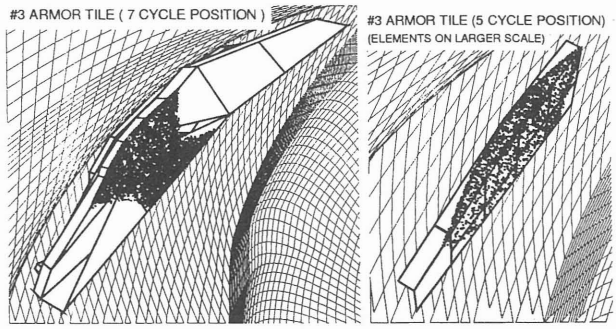

Fig.2: Comparison of the NBI-3 armor tile in the 7th and 5th cycle LHD campaign position.