§17. Magnetic Configuration Effects on Fast Ion Losses Induced by Fast Ion Driven Toroidal Alfvén Eigenmodes in the Large Helical Device

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One of the critical issues in fusion plasma is good confinements of α particles for avoiding α particle-induced damage of plasma facing components as well as enhancement of self-heating [1]. Avoiding that significant loss of alpha particles due to fast-ion-driven magnetohydrodynamic (MHD) instabilities such as Alfvén eigenmodes (AEs) [2], better understanding of loss process of fast ion due to fast-ion-driven MHD instabilities is required to find a method to control and/or reduce fast-ion losses. Anomalous transport of co-going beam ions due to toroidal Alfvén eigenmodes (TAEs) has been so far recognized in LHD by an E//B neutral particle analyzer with a tangential line of sight, and scintillator-based lost-fast ion probe (SLIP) at magnetic axis position in the vacuum field (R_{ax}) of 3.60 m [3, 4].

There are three negative-ion-based neutral beam (NB) injectors on the LHD and total power more than 15 MW can be injected having the beam energy of 180~190 keV. The beam ion loss from the LHD is measured with an SLIP. The SLIP is essentially a magnetic spectrometer, providing information on the energy E and pitch angles $\chi=\arccos(v_{//}/v)$ of escaping fast ions simultaneously. Here, v and $v_{//}$ indicate the velocity of fast ion and the velocity of fast ion parallel to the magnetic field, respectively.

The energetic ion loss study was carried out in three typical magnetic configurations, i.e. the "inward-shifted configuration" of R_{ax_vac}=3.60 m, "standard configuration" of R_{ax_vac}=3.75 m, and "outward-shifted configuration" of R_{ax_vac}=3.90 m. In this study, the magnetic field strength B_t was varied from 0.60 T to 0.90 T, where the direction of B_t is in the counter clockwise from the top view of the torus. In all shots of this experiment, m~1/n=1 TAE of which peak position locates r/a~0.6 was excited.

In NBI heated plasmas where the magnetic axis position is (R_{mag}) shifted outward to R_{mag}=3.75 m due to the Shafranov shift, the normalized losses by fast ion density ($\Delta\Gamma_{SLIP}/\{P_{NBco}\tau_{se}\}$) are nearly in proportion to the TAE magnetic fluctuation amplitude (b_{TAE}). $\Delta\Gamma_{SLIP}/(P_{NBco}\tau_{se})$ tend to be a quadratic dependence on the b_{TAE} in the case of larger R_{mag}(=3.85 m), and finally much stronger dependence in the largest case of R_{mag}=4.00 m, as shown in Fig.1.

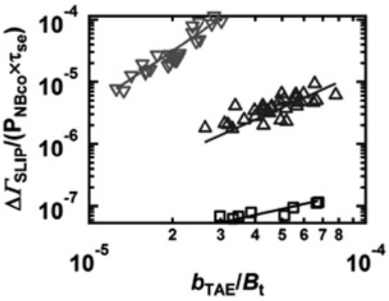

Fig.1 Dependence of loss fluxes on the relative TAE magnetic fluctuation amplitude at the magnetic probe in plasmas with R_{mag}=3.75 m(squares), 3.85 m(triangles) and 4.00 m(inversed triangles).

There are two candidates for explaining the changes of the dependences. One is that width of eigenfunction of TAE is wider because of flattening of rotational transform due to Shafranov shift. Wider eigenfunction make the loss process diffusive (quadratic) from convective (linear) losses, because fast ions exist away from the loss domains in phase space can be lost diffusively [5]. Second is due to enlargement of loss boundary due to Shafranov shift. The strong dependence might show strong diffusion: it shows fast ions would easily fall into the loss cone. It will lead to a stronger dependence of the loss flux on TAE amplitude. Orbit simulation of TAE induced loss using DELTA5D [6] is ongoing.

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