§12. Energetic Ion Losses Caused by MHD Activity Resonant and Non-resonant with Energetic Ions in LHD

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To realize a self-sustained D-T burning plasma, fusion-born energetic alpha particles (α's) should be confined long enough to heat the bulk plasma[1]. In addition to this, loss of α's should be controlled since the localized loss might damage plasma facing components. The principal concern is that D-T produced α's and super-Alfvénic ions such as beam ions destabilize energetic-ion-driven magnetohydrodynamic (MHD) instabilities such as Alfvén eigenmodes[2] (AEs) because those instabilities can potentially cause losses of energetic ions through wave-particle resonance. Recently, the effect of MHD mode non-resonant interactions with energetic ions such as edge localized mode[3] (ELM) is also of great concern since the transport of energetic ion may be affected through not only wave-particle resonance but also stochastization of energetic-ion orbits[4].

Measurements of the energetic-ion losses induced by the TAE and ELM modes are performed in NB-heated LHD plasmas. Strongly-excited TAE having 20~40 kHz is observed in the time window from t~4.0 s to 4.7 s by means of MPs. It shows that increment of loss flux increases with TAE amplitude as expected. Also low-frequency fluctuations less than 20 kHz are seen (Fig. 1 a)). Plots of energetic-ion loss as a function of ELM amplitude indicate a dispersed structure (Fig. 1 c)).

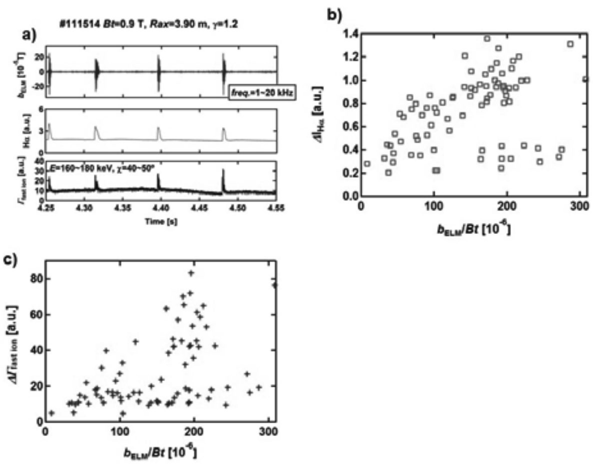

Fig. 1 a) Typical time traces of magnetic fluctuation of ELM range of frequency, Hα signal, and signal of lost-fast ion. b) Increment of Hα signal as a function of ELM amplitude measured at magnetic probe position (b_{ELM}) normalized by toroidal magnetic field strength. There are no clear dependence. c) Increment of fast-ion loss as a function of b_{ELM}/Bt. It has a dispersed structure.

A numerical simulation based on orbit following models including magnetic fluctuations is performed to understand the TAE or ELM-induced energetic-ion loss process. Increment of loss flux increases quadratically with amplitude of TAE magnetic perturbation measured by MP; the tendency agrees with experimental results. The increment of energetic-ion loss as a function of ELM amplitude is shown in Fig. 2. Energetic-ion loss increases almost linearly with b_{ELM}/Bt when we fix an initial phase of ELM. We found that ELM-induced energetic-ion loss depends on the mode phase of the ELM. In experiments, the ELM could take on any initial phases; therefore, this is roughly consistent with the dispersed structure observed experimentally. However, the phase effect seems to be small compared with the observed scattering of the data shown in Fig. 2. Large magnetic fluctuations related to ELMs may modify the MHD equilibrium structure near the edge appreciably.

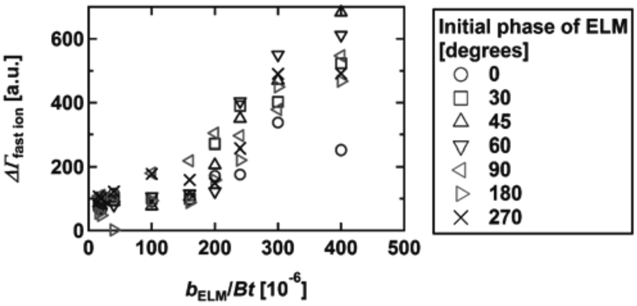

Fig. 2 Increment of energetic-ion loss as a function of ELM amplitude at the magnetic probe position from the calculation. The incremental loss of energetic-ions increases almost linearly with ELM amplitude in each case. Energetic ion loss is dependent on the initial phase of ELM.

Let us discuss the reason why an ELM phase affects the energetic-ion loss. In ELM case, the poloidal distribution of energetic ion is largely changed due to the initial phase of the mode compared with TAE case. In this experiment, the frequency of the ELM is much lower than the orbital frequency of the energetic ions. Then loss points of energetic ions can be largely changed toroidally or poloidally due to ELM phases because the shape of fluctuation does not change during the toroidal or poloidal transit time of the fast ions. The detectable region of the SLIP on the LCFS is overlaid. Because of the choice γ = 1.20, the SLIP only can cover from -180 degrees to -60 degrees and 60 degrees to 180 degrees in poloidal angle on the LCFS. Due to this fact, the energetic-ion loss depends on the phase of the ELM fluctuations.

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3) Zohm, H.: Plasma Phys. Control. Fusion **38** (1996) 105.
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