§41. Fast-ion Transport during Repetitive Burst Phenomena of Toroidal Alfvén Eigenmodes in the Large Helical Device

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It is essential to understand the instabilities driven by alpha particles and the resultant behaviors of alpha particles induced by MHD instabilities such as TAEs and energetic particle continuum mode (EPM) under reactor relevant conditions. LHD equips with unique negative ion based neutral beam injectors (N-NBs) at E_b of ~190 keV, which satisfy the reactor relevant excitation conditions of Alfvén activities with the wide parameter range of $v_b/\ v_A$ from 0.3 to ~ 4.0 at the relatively low toroidal magnetic field B_t = 0.75 T. The Alfvén activities for LHD discharges have been identified during N-NB heating and features have been characterized by sophisticated studies. Figure 1 (a) shows the time evolution of plasma parameters, when we observe the repetitive bursts of Alfvén activities [1]. Figures 1(b) and (c) show the spectrogram of the magnetic fluctuation and the fast ion loss signal I_{SLIP}, respectively, during bursting TAEs. The detected fast ion losses have the pitch angle ($\chi = \arccos(v_{//}/v)$) of ~ 130 degrees from the image monitored by the ICCD camera. In other time window, the n = 2 mode disappears, when the counter-injected NB2 with E_b of 160 keV is terminated. The bursting fast-ion losses have about every 5 ~ 10 ms intervals. The feature has the rise time of ~ a few hundred μs, which is almost the same rise time of magnetic fluctuations. The slow recovery time of 5 ~ 10 ms for fast ion loss signals in figure 1(c) seems to be governed by n = 2 down chirping mode in figure 2(b) until the subsequent burst starts.

The effective confinement time of energetic ions τ* was evaluated to be 2 ~ 3 ms during TAE bursts from the analysis of the degradation of stored energy W_p by S. Yamamoto *et al.* The TAE induced fast ion loss rate τ_{MHD}/τ^* = 0.7/3.0 = 0.23 at t = 1.057 s. On the other hand, the fast ion loss rate can be estimated to be $\delta I_{SLIP}/I_{SLIP}$ = 0.60, which is much higher than τ_{MHD}/τ^*. Thus it is found that the loss location of fast ions is localized during TAE burst activities.

As a collaboration research with Osaka University and Tohoku University, the polycrystalline Ce: YAG samples were developed. The large size of Ce:YAG ceramics mounted on the SLIP head has got successfully fast ion signals during 12th cycle of LHD experiments [2].

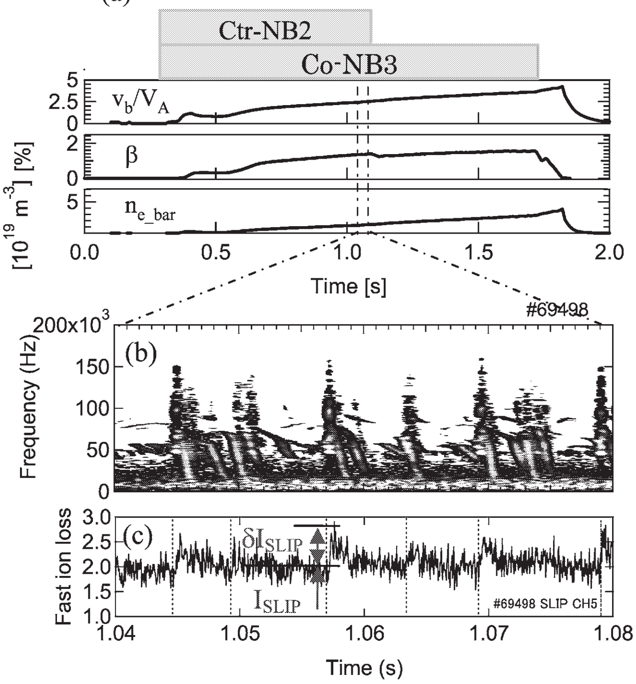

Fig. 1. Time evolution of fast ion losses induced by repetitive TAE bursts for n = 1 at the robust frequency of ~50 kHz and n=2 at the frequency sweeping down from 80 to a few ten kHz. (a) Discharge waveforms for N-NBs, v_b/v_A, beta value, and line averaged density. (b) Spectrogram of magnetic fluctuations, (c) Fast ion loss signal I_{SLIP}. The difference of fast ion loss signal before and after TAE burst corresponds to δI_{SLIP}.

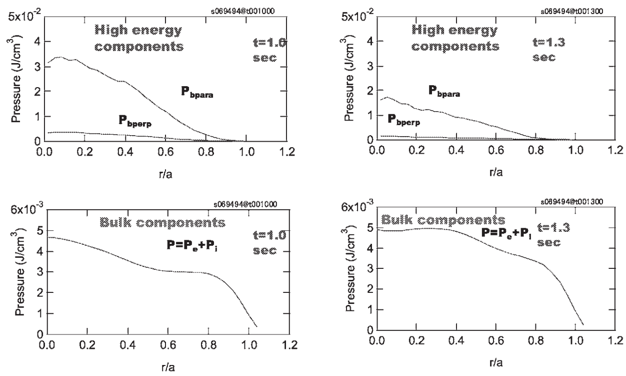

Fig.2 Fast ion pressure profiles for perpendicular and parallel components produced by co- and counter- NB injections obtained from FIT code. The lower graph shows the bulk (thermal) pressure profile obtained from measured Te and ne. The discharge #69494 is analyzed at t = 1.0 s.

1) Nishiura, M., *et al.*, Proceedings of 22nd IAEA FEC, 13-18 October 2008, Geneva, Switzerland.
2) Hirouchi, T., *et al.* J. Nucl. Materials 386-388(2009)1049.