§52. Evidence of Clump-hole Pair Creation in the Fastion Velocity Space during Bursting AE-activities

Osakabe, M., Itoh, T., Isobe, M., Toi, K., Ogawa, K. (Dept. Energy Eng. Sci., Nagoya Univ.),
Kobayashi, S., Nagaoka, K., Takeiri, Y., LHD-group

The influence of Alfvén Eigenmodes (AE) on behaviours of energetic particles are one of the most important issues in fusion reactor research since they might affect the confinement property of fusion-born alphas and degrade the heating efficiency of the alpha particles. The spontaneous formation of clump-hole pair in the energy/spatial distribution of fast-particles with the instability of plasma, including AEs, is theoretically predicted by Berk and Breizman[1]. In their theory, the down(up)-sweeping of the instability frequency is related to the down(up)-shift of clump(hole) energy and/or the radial outward(inward) shift of its spatial location. On LHD, the formation of clump-hole pair with a bursting activity of toroidicity induced AE(TAE) was observed in the fast-ion energy spectra by using a tangential neutral particle analyzer[2]. In the observation, the clump-hole pair creation was clearly seen and the pair creation is considered to be due to the radial excursion of fast-ions with the bursting TAE activities. On the other hand, the pair creation in the velocity space was not clear since the time resolution for energy measurement of fast-neutrals was not high enough.

To clarify the clump-hole pair formation in velocity space, time resolution of the NPA electronics was improved and the change of fast neutral energy spectra during TAE activities are measured. A typical change of the energy spectra during the mode-activity, time evolution of the mode amplitude and its frequency spectrogram are shown in Fig.1. These figures are obtained by accumulating those data for 13 similar events and by setting the zero of time axis to the time when the mode amplitude is maximized. The instability shown in the figure is TAE. Its toroidal mode number is 1 and the poloidal mode numbers are 1 and 2. As shown in the figures, neutral flux of around 150keV was increased with the mode activity. This increase corresponds to the clump formed in the fast-ion energy spectra with TAE. The neutral flux of around 190keV were decreased with the mode activity as shown in Fig.1(d). This correspond to the hole creation by the instability. The initial frequency of the mode was 72kHz. Its frequency decreases to 70kHz at t=0 and reaches to 67kHz at the end. At the same time, the energy of the clump changed from 185keV to 150keV. This relation between the shifts of the clump energy and the mode frequency is consistent with the theoretical prediction by the Berk-Breizman (B-B) model. In Fig.2, a slowing-down time distribution of fast-ions on the NPA sight line are shown and the lifetimes of fast-ions on their orbits are shown. In the figure, the region where $\langle r/a\rangle_{orbit} > 0.85$ corresponds to the loss region since lifetimes of fast-ions are smaller than the truncation limit of orbit calculation. As shown in the figure, slowing-down times of fast-ions from 185keV to 150keV are greater than 1ms in the confined region on the NPA sight line. On the other hand, the energy shift of clump occurred within the time duration of 0.5ms. Thus, it is impossible to explain the energy shift by the simple classical slowing-down process. For the relation between energy of the hole and mode frequency, neither the up-shift of hole energy nor the up-sweeping of the mode frequency was observed. This is also consistent to the B-B model. Since the injection energy of Neutral Beam (NB) of this discharge is about 190keVand the hole is created at almost the same energy, the hole energy was bound to 190keV. Consequently, the up-sweeping of the mode frequency did not occur for this activity.

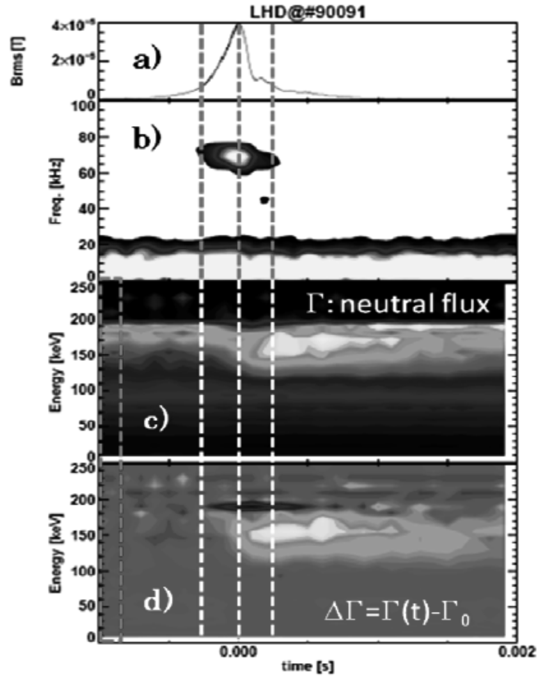

Fig. 1 (a) Time evolution of TAE mode amplitude being measured by a Mirnov-coil, (b)its frequency spectrogram, (c) fast neutral energy spectra, and (d) deviations of fast neutral flux from that during a quiescent phase(t=-0.001~-0.0008s).

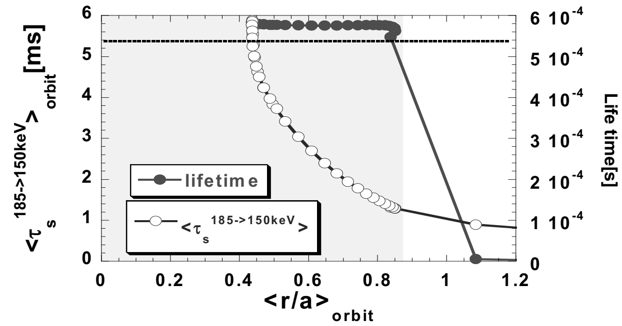

Fig. 2 Distribution of slowing down times of fast-ions (○) and that of lifetimes of their orbits (●) on the sight line of tangential NPA. Slowing-down times are averaged along their orbits. The dashed lines show the truncation limit, which is 0.54ms in life time, of orbit calculations.

1) H.L.Berk, *et. al.*, Phys. of Plasmas **6**(1999)3102
2) M.Osakabe, *et.al.,* Nucl. Fusion **46**(2006)s911