§33. Studies of Lost Energetic Ions Caused by Alfvén Eigenmodes in Helical Plasmas

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Good confinement of energetic particles (EPs) in magnetically confined fusion is essential in realizing a fusion reactor since energetic alpha particles generated by fusion reactions play an essential role as a primary heating source in the future burning plasmas. Therefore deep understanding for interplay between EPs and EP-driven magnetohydrodynamic (MHD) instabilities is required. In order to investigate transport and/or loss of energetic ions due to EP-driven MHD instabilities, we developed and installed Faraday cup-type lost fast-ion probe (FLIP), which can measure the energy and pitch angle of detected ions with high time resolution, into Heliotron J in the collaboration between IAE, Kyoto University and NIFS[1). Our main purpose is to clarify the mechanism of interplay between EPs and EP-driven MHD instabilities in Stellarator/Heliotron plasmas by the comparison among Heliotron J, CHS and LHD.

The FLIP is consisted of eight thin aluminum plates as electrode covered with molybdenum probe head having double small slits in Heliotron J. Probe position can be adjusted to locate just outside the last close flux surface (LCFS) of each magnetic configurations. The double small slits of probe head can select ions, which were escaping from confinement region. There are eight electrode plates which can detect ions having different energy E and pitch angle χ respectively, as shown in Fig. 1. In the Fig. 1, pitch angle of 0 ~ 90 deg. corresponds to the co-going ions. The injection energy of NB is less than 30 keV of Hydrogen.

There are two tangential NBIs consisted of both co- and counter- injectors corresponding to beam line 1 (BL2) and BL1 in the condition of normal magnetic field direction $B_t > 0$. In the first experiment of FLIP, we investigated whether FLIP can only detect co-going ions produced by BL2. The FLIP locating at just outside LCFS can detect re-entering co-going ions in spite of observation of EP-driven MHD instability. Figure 2 shows the time evolution of signal of two electrodes named as channel A and E (ch-A and E) and ECH and NBIs. The plasma was produced by ECH, and heated by two NBIs which were turned on t=180 ms for BL2 (co) and t=200 ms for BL1 (ctr.). In our FLIP, positive and negative signals mean the detection of electron and ion, respectively. When BL2 was injected, single of ch-E having χ=10~25 deg. and E=14~42 keV of Hydrogen decreased and has negative value. This means we can detect co-going ion only by FLIP. Figure 3 shows the observation of the increment of ion current in ch-B synchronized with the busting energetic particle modes (EPMs) in NBI-heated Heliotron J plasmas. After NBI turned on, busting EPMs with intense magnetic fluctuation and frequency chirping were observed as shown in Fig. 3 (a) and (b). The amount of energetic ion loss flux was observed in ch-E scale with the amplitude of magnetic fluctuation of EPMs. This indicates that energetic ions were lost caused by the energetic-ion-driven EPMs.

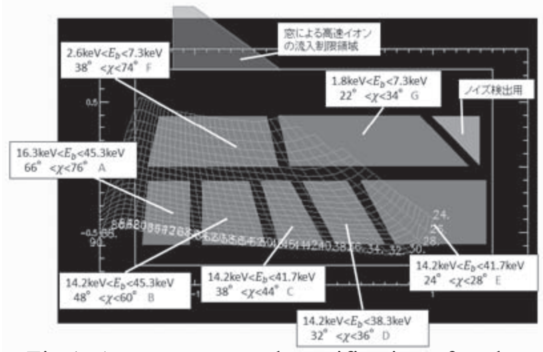

Fig.1, Arrangement and specification of each electrode plate of FLIP in Helitoron J.

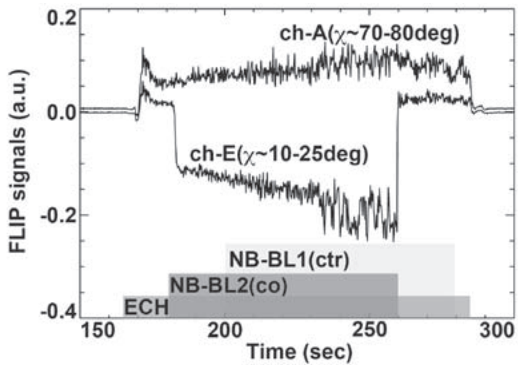

Fig.2, Detection of co-going energetic ions by FLIP in NBI-heated plasmas.

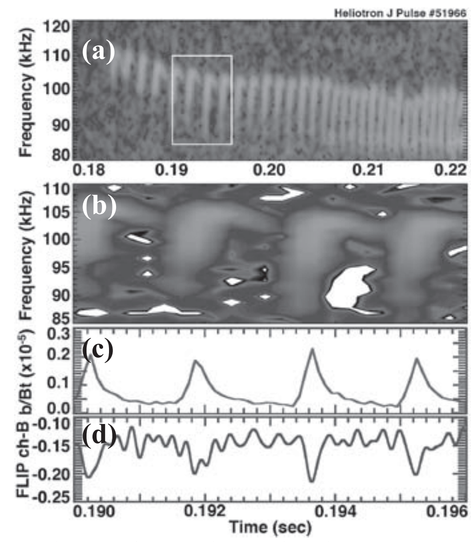

Fig. 3, Observation of lost ions caused by bursting EPMs.

1) Ogawa, K., et. al., PFR **8**, (2013) 242128.