§25. Studies of Lost Fast Ions Induced by Fast Ion Driven MHD Instabilities in Helical Plasmas

Ogawa, K., Isobe, M.,
Yamamoto, S., Sano, F., Mizuuchi, T., Nagasaki, K., Okada, H., Minami, T., Kado, S., Kobayashi, S., Ohshima, S., Sano, T., Nakayama, Y. (Kyoto Univ.)

Good confinement of fast particles (FPs) in magnetically confined fusion plasmas is essential in realizing a fusion reactor since alpha particles generated by D-T fusion reactions play an essential role as a primary heating source in future burning plasmas. Therefore deep understanding for interplay between FPs and FP-driven magnetohydrodynamics (MHD) instabilities is required. In order to investigate transport and/or loss of fast ions due to FP-driven MHD instabilities, we developed and installed Faraday cup type lost fast-ion probe (FLIP), which can simultaneously 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 FPs and FP-driven MHD instabilities in Stellarator/Heliotron plasmas by the comparison among Heliotron J, CHS and LHD results.

The FLIP is composed of eight thin aluminum plates as electrode covered with molybdenum probe head having double small aperture in Heliotron J. Probe position can be adjusted to locate just outside the last close flux surface of each magnetic configuration. The double small apertures of probe head can select ions, which are escaping from confinement region. There are eight electrode plates, which can detect ions having the energy of E = 2 ~ 45 keV for Hydrogen and pitch angle χ = 90 ~ 150 deg. (co-going ions). The injection energy of neutral beams is less than 30 keV of hydrogen in Heliotron J. There are two tangential NBIs consisted of both co- and counter- injectors named as beam line 2 (BL2) and BL1 in the condition of normal magnetic field direction $B_t > 0$. In the experiment campaign of FY2013, we successfully observed fast ion loss induced by bursting and intense energetic particle mode (EPMs), whose frequency is typically 100 kHz, by using the FLIP in Heliotron J plasmas. In last experimental campaign, FY2014, we observed fast ion loss induced by other FP-driven MHD instabilities whose frequency is different from typically observed EPMs, as show in Fig. 1. The timing of increase in lost ion flux of channel 2 is synchronized with FP-driven instability with the observed frequency of 50 kHz rather than EPM with 90 kHz. The channel 2 of FLIP can detect lost ion having E = 16 ~ 45 keV / χ = 110 ~ 120 deg.. Full orbit calculation indicates that the detected ions should originate from plasma peripheral region where the observed FP-driven MHD instability is locally excited. Amount of lost ion flux is proportional to magnetic fluctuation amplitude of the observed FP-driven MHD instabilities.

We are newly developing a scintillator type lost ion probe (SLIP) to get higher resolution of energy and pitch angle of lost ions, and to reduce the noise caused by thyristor. Since FP-driven MHD instabilities including EPMs and global Alfvén eigenmodes (GAEs) are excited by both co- and counter-going ions, the new SLIP can measure the fast ions with E = 2 ~ 45 keV for Hydrogen and pitch angle χ = 40 ~ 140 deg. corresponding to both co- and counter-going ions. Figures 2 (a) and (b) show the strike mapping and schematic drawing of the SLIP. The luminescence of scintillator (ZnS:Ag) can be measured by CCD to have higher resolution of energy and pitch angle of lost ions, and nine-channel photomultiplier tube to have high time resolution.

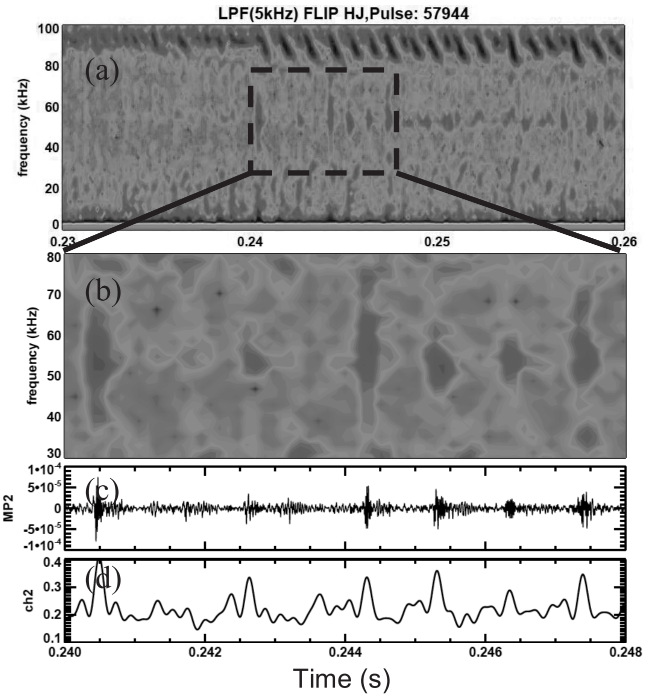

Fig. 1, Time evolution of (a) power spectrum of magnetic fluctuation, (b) expanded view of (a), (c) magnetic fluctuation of mode and (d) channel 2 signal of FLIP.

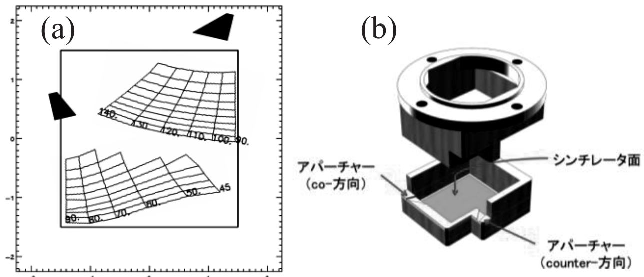

Fig. 2 (a) Strike mapping and (b) schematic drawing of new SLIP, respectively.

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