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§26. Study of Field Optimization of Fast Ion Confinement by Using ICRF Heating in Heliotron J

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Main purpose of this study is to optimize fast ion confinement by using ICRF heating in a helical-axis heliotron device, Heliotron J on the basis of results of several helical devices. The magnetic field of Heliotron J is non-symmetric configuration. The profile measurement in the poloidal cross section seems to be important as well as the pitch angle distribution of the fast ions in the three-dimensional magnetic field of Heliotron J. The wide range observation (about 25% in the poloidal cross section) of fast ions is performed by changing the line of sight of the charge-exchange neutral particle energy analyzer (CX-NPA) in two directions for three bumpinesses. The experiment was performed in the minority heating using hydrogen and deuterium as a minority and a majority, respectively. The minority ratio is about 10%. The bumpinesses (B_{04}/B_{00}, where B_{04} is the bumpy component and B_{00} is the averaged magnetic field strength) are selected to be 0.15 (high) and 0.06 (medium, STD) at the normalized radius of 0.67 in this study.

The dependence of the bumpiness and the heating position has been investigated and both conditions are found to affect fast ion generation and confinement. Two ICRF antennas are installed in the poloidal cross section aligned vertically on the both sides of the mid-plane. In the case of heating using two antennas, peaked profile was observed in the vertical angle scan of the CX-NPA near the plasma corner-section. In this campaign, to clarify the antenna position effect on the measured fast ion flux, each antenna is used separately in the high bumpiness configuration.

The experimental condition is as follows: the magnetic field strength is 1.25 T, the line-averaged electron density is 0.4×10^{19} m^{-3} and the ICRF power of 0.2 MW is injected into a target plasma produced by a 70-GHz ECH. The energy spectra of several vertical angles are shown in Fig. 1 for the case of the lower-side antenna. Figure 1 (a) is the case of the horizontal angle of 0°, where the CX-NPA observes the plasma corner section and Fig. 1 (b) is the case of 6°. The line of sight at the vertical angle of 0° crosses the plasma minor axis and the vertical angle of 6° corresponds to the normalized minor radius of 0.4 in each plot. The ion temperature before ICRF pulse injection is less than 0.2 keV. The slope of the energy spectrum at 0° in Fig. 1 (a) is the smallest among five cases, then, fast ions are well confined in this area. The further the vertical angle moves away from 0°, the steeper the slope of the energy spectrum is. In comparison to the both antenna case, the distribution is a little bit different. In that case, fast ions distribute asymmetrically against the vertical angel of 0°, whereas fast ions in the one antenna case are observed almost symmetrically on the both sides. The energy spectra in Fig. 1(b) for the horizontal angle of 6°, the vertical angle dependence is very small as the both antennas case. The small change is found only at the vertical angle of 6°. The CX-NPA measurement angle dependence for the upper-side antenna is similar to the lower one.

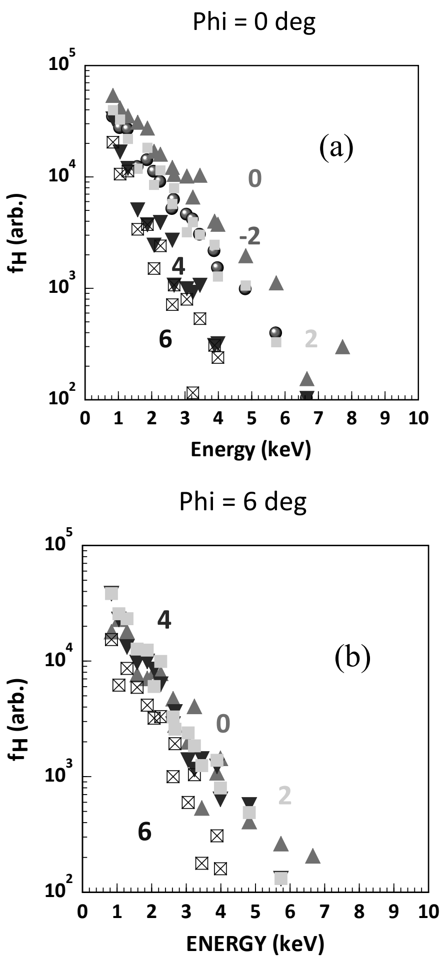

Fig. 1 Minority hydrogen energy spectra in the case of the lower-antenna heating. The upper plot (a) is for the horizontal angle of 0° and (b) is for 6°.

To understand the experimental results, a Monte-Carlo simulation has been developed. For the calculation of measured CX fluxes, the three dimensional distribution of the fast ions is required. For this purpose, the test particles in the calculation are summed up after the saturation of averaged energy and statistically improved. In the beginning, the toroidal profile and radial profile are calculated for the three bumpiness configurations. The toroidal profile coincides with the result in the former calculation where 100 times test particles were used. From the calculation results, the fast ions at the plasma corner section are larger than those at in the straight section in the high bumpiness configuration. For other configurations, such tendency is not observed and the fast ions distribute uniformly in the toroidal direction. For the next step, the energy spectra for three dimensional positions will be discussed and compared with the measured CX-NPA fluxes.

1) H. Okada, T. Mutoh, et al., "Two-Dimensional Distribution of Fast Ions Generated by ICRF Minority Heating in Heliotron J", 19th ISHW, Sep.16-20, 2013, Padova, Italy, K7.