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ヘリオトロンJにおけるICRF加熱で生成された高速イオンの解析
Analysis of Fast Ions Generated by the ICRF Heating in Helitoron J

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Fast-ion confinement is one of most important issues for helical devices since the alpha particle heating efficiency in a fusion reactor depends on the loss cone structure for fast ions in velocity space. The toroidal ripple (bumpiness) of the magnetic field strength is one of key parameters for enhancing confinement in the Heliotron J (R_0 = 1.2 m, a = 0.1-0.2 m, $B_0 \leq$ 1.5 T) configuration. The fast-ion velocity distribution has been investigated using fast protons generated by ion cyclotron range of frequencies (ICRF) proton-minority heating in Heliotron J with a special emphasis on the effect of the bumpiness and the heating position. Initial results for Monte-Carlo simulations of fast ions (protons) obtained and the effects of the configuration had been discussed, where the calculation was performed for the energy spectra in relatively narrow region (< 10 keV). In this paper, the energy spectra are extended up to 20 keV by increasing the number of test particles.

Figures 1(a) to (c) show typical calculated energy spectra for the three bumpinesses at the pitch angle of 120°, where the fast ion flux is largest in the experiment. In these figures, the vertical axis show the logarithm of the ion counts in the bounded pitch angle range from 115° to 125° in pitch angle. The experimental values are also indicated by open symbols. The calculation reproduces the high-energy tail up to 20 keV, which was measured only in the high bumpiness case (see Fig. 1(a)). No detectable data was obtained in the charge exchange neutral analyzer (CX-NPA) measurements for energies above 6 and 8 keV for the medium and low bumpinesses, respectively. The measured and calculated energy spectra are also identical for the medium and low bumpinesses. Thus, the better production and confinement of fast ions in the high bumpiness is probed in the Monte-Carlo calculation results.

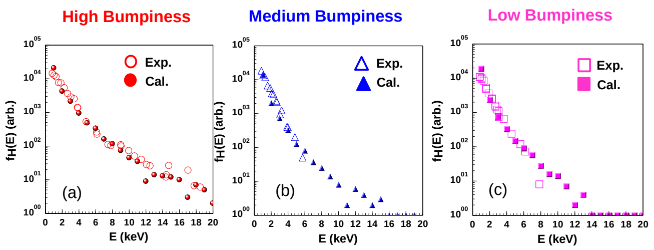

Fig. 1 The energy spectra from CX-NPA measurement (open symbols) in experiment and from Monte-Carlo calculation (solid symbols) for three bumpiness cases. They are for the (a) high, (b) medium, and (c) low bumpinesses, respectively.

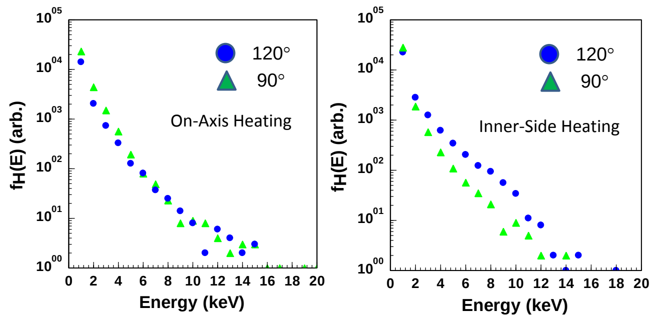

Fig. 2 Calculated energy spectra of 90° and 120° in pitch angle for the on-axis heating (a) and the inner-side heating (b).

The position of ion cyclotron layer was shifted by changing the injected wave frequency in the medium bumpiness experiment. The fast ions were large in the on-axis case comparing with those in the inner-side resonance case for centre chord measurement (110° in pitch angle) of the CX-NPA. The calculated energy spectrum at the pitch angle of 90° in the on-axis heating is slightly larger than that in the inner-side heating case. However, the fast ions at 120° in the inner-side heating case are larger than those at 90°. The averaged energy of total fast ions in the calculation is larger in the inner-side case than in the on-axis case. This result is consistent with the experimental fact that the bulk heating efficiency in the minority heating is better in the inner-side heating case.