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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分布の配位依存性
Configuration dependence of fast ion distribution generated by ICRF heating in Heliotron J

岡田浩之[1]、 村上弘一郎[2]、小林進二[1]、 水内亨[1]、長崎百伸[1]、南貴司[1]、山本聡[1]、大島慎介[2]、武藤敬[3]、木島滋[1]、史楠[1]、臧臨閣[2]、沙夢雨[2]、剣持尚輝[2]、笠嶋慶純[2]、原田伴誉[2]、佐野匠[2]、大谷芳明[2]、丸山正人[2]、野口正樹[2]、中村祐司[2]、佐野史道[1]
OKADA Hiroyuki[1], WATADA Hiroto[2], MURAKAMI Koichirou[2], KOBAYASHI Shinji[1], MIZUUCHI Tohru[1], NAGASAKI Kazunobu[1], MINAMI Takashi[1], YAMAMOTO Satoshi[1], OHSHIMA Shinsuke[2], MUTOH Takashi[3], KONOSHIMA Shigeru[1], SHI Nan[1], ZANG Ling[2], SHA Meiyu[2], KENMOCHI Naoki[2], KASASHIMA Keijun[2], HARADA Tomotaka[2], SANO Takumi[2], OTANI Yoshiaki[2], MARUYAMA Masato[2], NOGUCHI Naoki[2], NAKAMURA Yuichi[2], HASHIMOTO Kouhei[2], NAKAMURA Yuji[2], SANO Fumimichi[1]

[1]京大エネ理工研、[2]京大エネ科、[3]核融合科学研
[1]IAE Kyoto Univ., [2]GSES Kyoto Univ., [3]NIFS

Fast ion confinement is a critical issue for helical devices, since magnetic field ripple is ordinarily large. In Heliotron J, a low-shear helical-axis heliotron (R_0 = 1.2 m, a = 0.1-0.2 m, $B_0 \leq$ 1.5 T), fast ion velocity distribution in the low density region has been investigated using fast protons generated by ICRF minority heating with special emphasis on the effect of the toroidal ripple of magnetic field strength (bumpiness) and heating position [1, 2]. The majority is deuterium and the minority is hydrogen. The minority ions are easily accelerated in this heating mode.

The high bumpiness among three bumpiness configurations was preferable for the fast ion confinement in the pitch angle scan experiment of the CX-NPA under the on-axis heating condition. In medium bumpiness, the two locations of cyclotron resonance layer were examined. The effective temperature, which is estimated from the slope of the energy spectrum between 1 keV and 7 keV, of the minority proton in on-axis heating was higher than that in the inner-side heating; however, the bulk deuteron temperature in on-axis heating was lower. It is not consistent with the heating scheme since most rf input power is absorbed by minority ions in our experimental condition. Fast ion’s distribution is occasionally localized in real space and there is the loss region in velocity space in the high energy area. The result of fast ion observation should be analyzed including such effects and the configuration dependence of such effects should be clarified.

The two dimensional CX-NPA scan for the line of sight is performed for the three bumpiness configurations in on-axis heating condition. The scan region is from -2° to 12° for the horizontal angle and from -2° to 6° for the vertical angle. The toroidal position of the line of sight is changed in the horizontal angle scan as well as the pitch angle of the observed fast ions. The position of the line of sight in the oblique cross section is changed in the vertical angle scan. For the most angles, the effective temperature of fast minority ions and the bulk ion temperature in the high bumpiness are highest among three configurations. In the high bumpiness case only, the minority effective temperature profile is asymmetrical against the magnetic axis at -2° and 0° of horizontal angle. In the larger horizontal angle, the profile is symmetrical against the magnetic axis as in other two bumpinesses. For the bulk ion temperature profile, no asymmetry is observed in all bumpinesses.

To understand the experimental results and to obtain the distribution of the fast ions in a plasma, Monte Carlo calculation is performed. The code used involves orbit tracing, Coulomb collisions and acceleration by the ICRF heating. In the calculation results, the generation of fast ions in the high bumpiness configuration is largest among three configurations. Calculated pitch angle dependence for the volume averaged fast ions agrees with the experimental result of the on-axis line of sight. The fast ions are populated more near the toroidal angle of 0° in the high bumpiness and the inner-side heating of the medium bumpiness. The analysis of the spatial distribution of the fast ions is in progress by comparing experimental data with simulation results.

[1] Okada H et al. 2007 *Nucl. Fusion* **47** 1346.
[2] Okada H et al. 2011 *J. Plasma and Fusion Res. SERIES* **6** 2402063.