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Dependence of Fast Ions Generated by ICRF Minority Heating on Pitch Angle and Spatial Position in Heliotron J

ヘリオトロンJにおけるICRF加熱での高速イオンピッチ角及び空間位置依存性

Hiroto Watada[1)], Hiroyuki Okada[2)], Shinji Kobayashi[2)], Hyunyoug Lee[1)], Tohru Mizuuchi[2)], Kazunobu Nagasaki[2)], Kiyoshi Hanatani[2)], Takashi Minami[2)], Satoshi Yamamoto[2)], Shinsuke Ohshima[3)], Takashi Mutoh[4)], Shigeru Konoshima[2)], Kiyofumi Mukai[1)], Shohei Aarai[1)], Tasuku Kagawa[1)], Takayuki Minami[1)], Yoshinobu Wada[1)], Koji Mizuno[1)], Fumimichi Sano[2)]
和多田泰士[1)], 岡田浩之[2)], 小林進二[2)], H.Y.Lee[1)], 水内亨[2)], 長崎百伸[2)], 花谷清[2)], 南貴司[2)], 山本聡[2)], 大島慎介[3)], 武藤敬[4)], 木島滋[2)], 向井清史[1)], L.Zang[1)], 荒井翔平[1)], 香川輔[1)], 南貴之[1)],和田善信[1)], 水野浩志[1)], 佐野史道[2)]

1) *Graduate School of Energy Science, Kyoto University, Gokasho, Uji, 〒611-0011, Japan*
京都大学大学院エネルギー研究科　〒611-0011　京都府宇治市五ケ庄
2) *Institute of Advanced Energy, Kyoto University, Gokasho, Uji, 〒611-0011, Japan*
京都大学エネルギー理工学研究所　〒611-0011　京都府宇治市五ケ庄
3) *Pioneerging Research Unit for Next Generation, Kyoto University, Gokasho, Uji, 〒611-0011, Japan*
京都大学次世代開拓ユニット　〒611-0011　京都府宇治市五ケ庄
4) *National Institute for Fusion Science, Toki,Gifu , 〒509-5202, Japan*
核融合科学研究所　〒509-5202　岐阜県土岐市下石町

Confinement of high-energy particles such as alpha particles is an important issue for plasma heating. In a previous research, different results of generation of fast ions and heating of major ions were obtained at central heating and torus inner-side heating in STD configuration. This finding is not consistent with heating mechanism of ICRF minority heating. The aim of this study is to carry out the investigation of the spatial distribution of fast ions in the wide area of the poloidal cross sections with a CX-NPA and to clarify the effect of generation and confinement of fast ions on magnetic field configuration (bumpiness). Dependence of energy spectrum on poloidal angle at torus-inner heating is clarified.

1. Introduction

Confinement of high-energy particles such as alpha particles is an important issue for plasma heating. Here, using fast ions generated by ion cyclotron range of frequencies (ICRF) minority heating in Heliotron J, generation and confinement of fast ions have been investigated experimentally.

This paper focuses on the behavior of fast ions with varying the toroidal ripple (bumpiness) of the magnetic field strength, which is one of key parameters for improved confinement in Heliotron J [1]. The bumpiness can be varied by altering the ratio of the coil current of two types of toroidal coils. The ratios of the current of toroidal coil A to that of toroidal coil B in this study are 5:1, 5:2 and 5:3, which are labeled as the high bumpiness, medium bumpiness and low bumpiness [1, 2], respectively.

In a previous research, which had focused on the dependences of effective temperature of hydrogen and deuterium temperature on heating position, the temperature of deuterium as major ions was founded to be higher when the resonance layer is torus inner-side than the case when resonance is located at the center of the plasma, although effective temperature of hydrogen as minority ions was higher

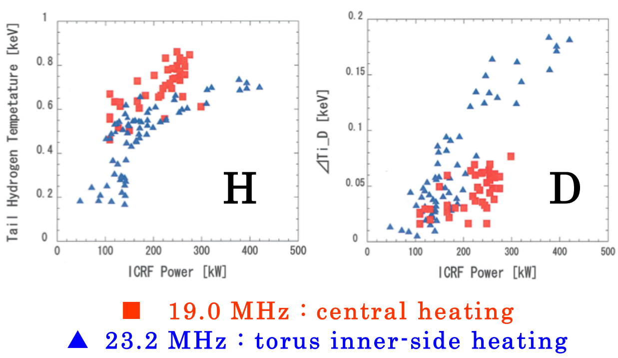

Fig.1 Heating position dependence of the effective temperature in the CX-NPA measurement line of sight is faced to magnetic axis.

in the center heating than inner-side heating. This finding is not consistent with the standard heating mechanism of minority heating (see Fig.1). A charge exchange neutral particle analyzer (CX-NPA) of E//B analyzer is used to detect energetic ions and to estimate the bulk ion temperature.

One of the candidates for this reason is that the measured energy spectrum does not represent the averaged fast ion energy spectrum since fast protons may be largely located in off-axis position of the plasma.

The aim of this study is to carry out the investigation of the spatial distribution of fast ions in the wide area of the poloidal cross section and to clarify the effect of generation and confinement of fast ions on magnetic configuration (bumpiness).

2. ICRF Experiments

An ICRF wave was injected into electron cyc1otron heated (ECH) plasmas. The ICRF frequency of 23.2 MHz was selected for the high bumpiness configuration and 19.0 MHz was selected for the low bumpiness configuration for the on-axis heating. The magnetic field is about 1.25 T on the plasma axis, the line-averaged electron density is 0.4 x 10^{19} m^{-3}, the 70-GHz ECH injection power is 0.30-0.35 MW, and the ICRF injection power is 0.25-0.30 MW. The minority ratio (H/H+D) is about 10%. The energy ranges of the CX-NPA are from 0.4 to 80 keV for hydrogen and from 0.2 to 40 keV for deuterium with a resolution of 4 to 10%. It can scan the line of sight in the toroidal direction from -10° to +18° and in the poloidal direction from -3° to 10°. The line of sight of the CX-NPA in the cross section at the toroidal angle 6.0° is illustrated in Fig.2. Varying the toroidal angle mainly alters the observed pitch angle. The distribution in the poloidal cross section can be measured by varying the poloidal angle of the line of sight of CX-NPA as shown in Fig.2.

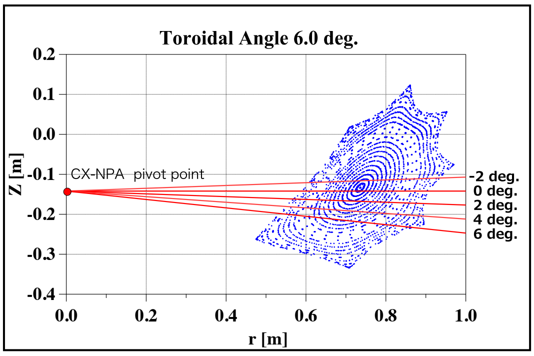

Fig.2 Line of sight of the CX-NPA in the plasma cross section at 6.0° in toroidal angle.

3. Magnetic Configuration Dependence of Fast Ions

The energy spectra of fast ions measured in the high bumpiness, medium bumpiness and low bumpiness at the toroidal angle 6° are illustrated in Fig.3. In the low bumpiness, the energy spectrum has week dependence in the poloidal poloidal direction. The behavior of the energy spectrum of the medium bumpiness is almost the same to that of the low bumpiness. The energy particle with the highest energy is measured in the high bumpiness. This is consistent with previous studies [3]. The poloidal angle dependence of energy spectra in center heating is clarified to be relatively large in high bumpiness, although the poloidal angle dependence in medium and low bumpiness configurations is weak.

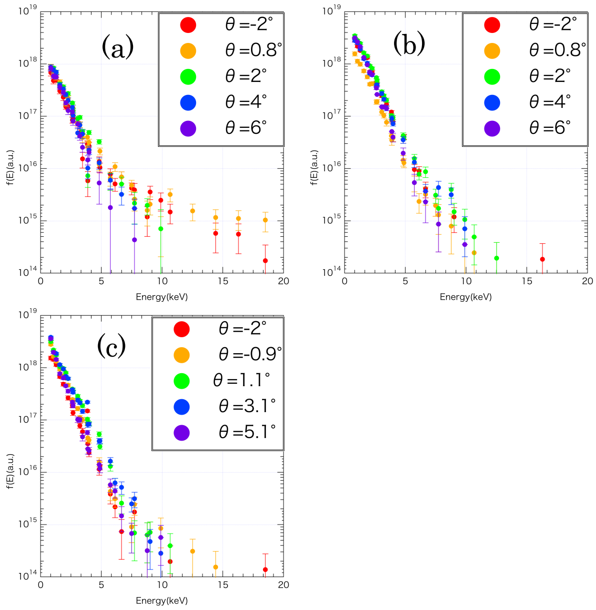

Fig.3 Energy spectra measured at the toroidal angle 6° for (a)high bumpiness, (b)medium bumpiness and (c)low bumpiness

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