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Ion Energy Balance Analysis Using Charge-Exchange Neutral Particle Analyzerin GAMMA10 Central-Cell

荷電交換中性粒子分析器を用いたGAMMA10セントラル部における イオンエネルギーバランス解析

Takashi Ishii, Yousuke Nakashima, Katsuhiro Hosoi, Hisato Takeda, Kazuya Ichimura, Hideaki Ueda, Shigehito Takahashi, Satoru Kigure, Satoru Hodaka, Tsuyoshi Imai
石井　貴、中嶋洋輔、細井克洋、武田寿人、市村和也、
上田英明、高橋樹仁、木暮　諭、保高　暁、今井　剛

Plasma Research Center,University of Tsukuba,
1-1-1,Tennoudai, Tsukuba, Ibaraki 305-8577,Japan
筑波大学プラズマ研究センター　〒305-8577　つくば市天王台 1-1-1

In the GAMMA 10 experiments using electron-cyclotron resonance heating (ECRH) with newly transmission systems, the increase of charge-exchange neutral fluxes were observed by CX-NPA. The electron temperature in the central-cell also increased from 22 eV to 53 eV by ECRH. In hot-ion mode that hot ions are generated by ICRF, it was investigated that the loss by coulomb collision of ion and electron occupied most of the ion-energy loss. In this estimation detailed analysis has been carried out in consideration for the error of both Ti and Te.

1. Introduction

It is an important subject to investigate fast ion behavior in order to discuss ion energy loss balance. In GAMMA 10, a charge exchange neutral particle analyzer (CX-NPA) has been installed perpendicularly to the magnetic axis to obtain hot ions in the central-cell. CX-NPA is a parallel-plate type energy analyzer that analyzes neutral particle from the energy of 0.2 keV to 30 keV. Recently the transmission system of ECRH in the central-cell was improved. Then plasma electron heating experiment using ECRHc has been performed and a significant increase of diamagnetism (DMcc) was observed in the period of ECRHc.

In this paper, the results of the neutral particle fluxes using CX-NPA are reported and the detail of ion energy balance is discussed based on the results of ion energy-loss code.

2. Experimental Data

Figure 1 shows the temporal behavior of DMcc and electron line density (NLcc). In this experiment, ECRHc is injected from 105 ms to 125 ms. It is obvious that DM immediately increased in the period of ECRHc. Figure 2 shows the radial profiles of plasma parameters in the central-cell: electron temperature and ion temperature. The core ion temperature increased from 1.8 keV to 3.9 keV and the core electron temperature increased from 22 eV to 53 eV by ECHc.

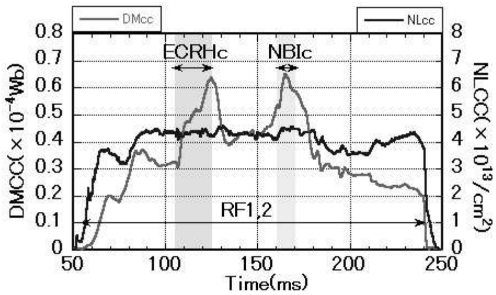

Fig.1 Temporal behavior of DM and NL

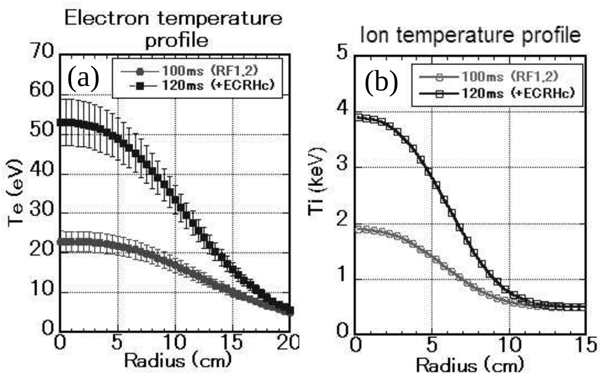

Fig.2 Temporal behavior of plasma parameters in the central-cell ECRH experiment.
(a) electron temperature (b)ion temperature

3. Analysis of Ion Energy Loss Balance

In this study, we assumed four processes of ion energy loss in order to clarify the detailed behavior of fast ion.

(1) Loss by coulomb collision between ion and electron.

$$P_{ie} \propto \frac{n_i \cdot n_e}{T_e^{3/2}}(T_i - T_e) \qquad (1)$$

(2) Loss by electric charge exchange reaction between ion and neutral hydrogen atom.

$$P_{CX}^{H_0} \propto n_i \cdot n_{H_0}(T_i - T_{H_0})\sigma_{cx}^{H_0} v \qquad (2)$$

(3) Loss by electric charge exchange reaction between ion and neutral hydrogen molecule.

$$P_{CX}^{H_2} \propto n_i \cdot n_{H_2}(T_i - T_{H_2})\sigma_{cx}^{H_2} v \qquad (3)$$

(4) Axial direction loss of ion.

$$P_{ax} \propto n_i \cdot \frac{n_i^{hot}}{n_i^{total}} \cdot \left(T_{i\perp} - T_{i//}\right)/\tau_{ii} \qquad (4)$$

The result of analysis showed in Fig. 3. Q_{ie} (r) means the surface integral of the function $P_{ie}(r')$ over r' from r'=0 to r'=r.

$$Q_{ie}(r) = \int_0^r P_{ie}(r')2\pi r' dr' \qquad (5)$$

Figure 3 shows that Q_{ie} decreased greatly when ECHc was applied. Q_{ie} occupied about 90% of total ion loss energy in the period of RF. This rate decreased to 80% with rising electron temperature in the ECRHc period. Another ion energy loss slightly increased with rising ion temperature in ECRHc. The total amount of loss energy also decreased from 33 kW to 18 kW.

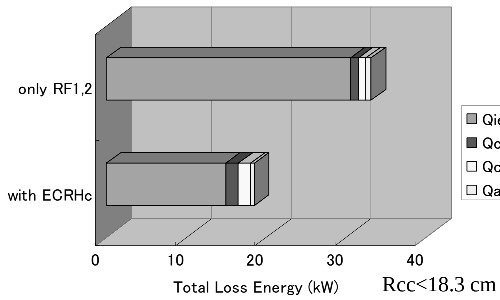

Fig.3 Total loss energy in the period of ECRH

When the energy balance of ions has been kept, this decrease should not occur as far as input energy to ions doesn't depend on electron temperature. In order to investigate this difference of total energy, we considered the error of ion and electron temperature. Figure 4 shows the total loss energy in consideration for the error of both Ti(0) and Te(0). Total loss energy increased in consideration for the error, but the difference still be existed. In the core area (Rcc<5.25 cm) the difference between total loss energy in RF and ECHc is much smaller than main area (Rcc<18.3 cm).

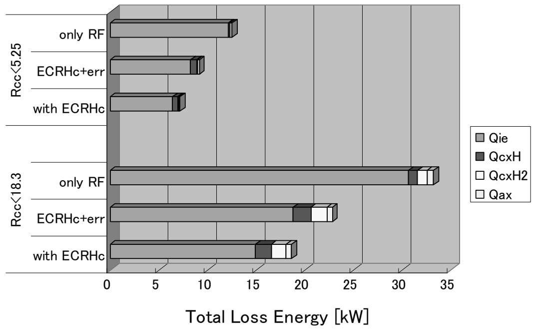

Fig.4 Total loss energy in the core and main area.
+err : in consideration for the error of both Ti(0) and Te(0)

4. Summary

In the GAMMA 10 central-cell, plasma electron heating experiment using ECRHc has been performed. From the experimental results, the diamagnetic signal in the central-cell has increased by ECRHc. The core ion temperature increased from 1.8 keV to 3.9 keV and the core electron temperature increased from 22 eV to 53 eV.

Recently investigation of the energy balance of the ion started and the analysis of heating effects in ECRHc has been performed for the first time in the case of newly transmission system in ECRHc. From the analysis, it was observed that loss by coulomb collision of ion and electron is reduced by ECRHc. The amount of Qie decreased from 30 kW (in the period of RF) to 15 kW. This decrease indicates that the relaxation of electron-drug due to hot-electron produced by ECRHc. However, we can't explain this decrease in spite of consideration for the error of ion and electron temperature. These results indicate that other factors concern ion energy loss.

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