§22. Effect of Re-entering Fast Ion Produced by NB on the Heating Power Profile and Velocity Distribution Function

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In the LHD, the reactor-relevant high-beta plasmas with the volume averaged beta value, <β>~5%, are achieved with about 0.5 T[1]. In such LHD high beta plasma, it is shown that most of fast ions produced by tangentially injected Neutral Beams (NB) are "re-entering fast ions" [2], which re-enter in the region of the closed flux surfaces after they have once passed out of the Last Closed Flux Surface. In order to evaluate the heating power profile and the velocity distribution function of fast ions with taking "re-entering fast ions" into account, we have developed the Monte-Carlo code based on the real coordinates (MORH)[2], which use the equilibrium magnetic field calculated by the HINT code[3].

In the LHD, the re-entering fast ion produced by tangential-NB was measured by using a hybrid directional probe[4] in order to validate the MORH and to investigate a behavior of the re-entering fast ion. A comparison of this measurement of "re-entering fast ions" with the MORH results needs to evaluate the heat flux of "re-entering fast ion" to the probe. In the low field such as the LHD high beta discharge, it is important for the comparison to consider the finite Larmor width. Then, to include the effect of the Larmor movements, the heat flux of "re-entering fast ions" is evaluated by MORH with the full-orbit (Fig.1). The heat flux evaluated by using the full-orbit is almost same value as the measurements. However, it takes a long time to calculate the full-orbit analyses. For reducing the calculation time, the finite Larmor width model is developed and is introduced to MORH with guiding center orbit. In the model, the circle with Larmor radius is calculated for each step of orbit tracings with the guiding center and the "imaginary particles" are assumed on its circle(see Fig. 2). Figure 3 shows the heat flux evaluated by the guiding center orbit and the finite Larmor width mode. In the Fig. 3, the heat flux evaluated by using the guiding center orbit and the finite Larmor width model is a little smaller than the measurement. Using the finite Larmor width model, the heat flux of re-entering fast ion can be evaluated by the MORH with the guiding center orbit in the low field. In addition, a calculation time of evaluation by the guiding center orbit is less than one-tenth of the evaluation by the full-orbit.

In the future, we will compare the calculations of the MORH with the measurements in high beta discharges with the higher field strength. Then, the assumption where fast ions are produced by NB only in the LCFS will be reviewed because some of the fast ions produced outside the LCRF are not promptly lost in the higher field. In addition, the behavior of the "re-entering fast ion" including its charge exchange loss will be investigated.

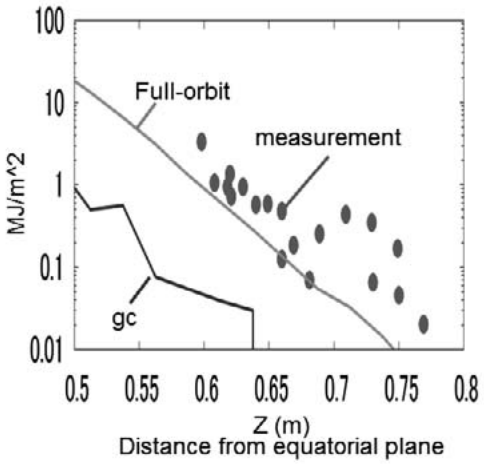

Fig. 1 Comparison of heat flux evaluated by MORH with experimental measurement (0.425 T).

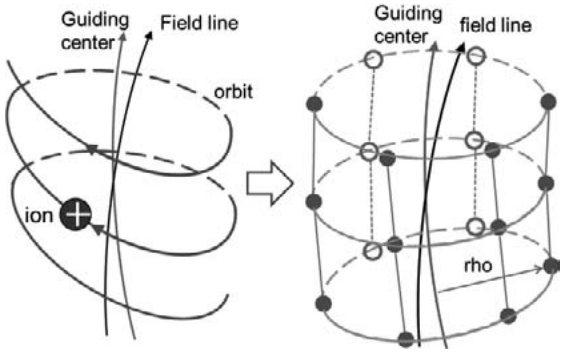

Fig. 2 Finite Larmor width model.

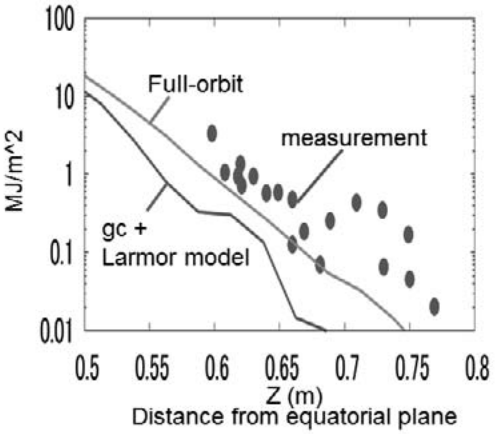

Fig. 3 Heat flux evaluated by using guiding center orbit and finite Larmor width model.

1) H. Yamada, et al., Nucl. Fusion **51** (2011) 09421.
2) R. Seki, et al., Plasma Fusion Res. **5** (2010) 014.
3)K. Harafuji, T. Hayashi and T. Sato, J. Comput. Phys. **81** (1989) 169.
4)K. Nagagoka *et al*., Rev. Sci. Instrum. 79 10E523 (2008).