§19. 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 14th and 15th campaign, the re-entering fast ion produced by tangential-NB was measured by using a hybrid directional probe[4](Fig. 1) in order to validate this code and to investigate a behavior of the re-entering fast ion. Figure 2 shows the increased temperature of this probe due to the tangential-NB. In Fig. 2, the point where the temperature of the probe increases by 10 degree shifts to outside with decreasing a field strength. This result indicates that "re-entering fast ions" re-enter from a longer distance in the lower field.

A comparison of the MORH results with this measurement of "re-entering fast ions" for the validation needs to evaluate the heat flux of "re-entering fast ion". The evaluation of the heat flux needs to consider the finite Larmor width because the Larmor radius of a typical fast ion produced by a NB is relatively large in the LHD high beta plasma. Then, the wall heat flux model of fast ions including the finite Larmor width has been developed. In developed model, the circle with Larmor radius is calculated for each step of orbit tracings with the guiding center and the particle is assumed to exist on its circle (Fig. 3).

Firstly, the particle orbit of this model is compared with the full-orbit calculation for the fast ion produced by the tangential-NB with 0.5 T in the collision less case. Figure 4 show the outmost points of the particle orbit. In Fig. 3, the outmost points of the developed model are almost the same as the full-orbit calculation. This result indicates that the developed model can reproduced the finite Larmor width.

We have a plan to compare the heat flux evaluated by developed model with that measured by hybrid directional probe in order to validate the MORH code. The behavior of the "re-entering fast ion" including its charge exchange loss will be investigated.

[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** (2008) 10E523.

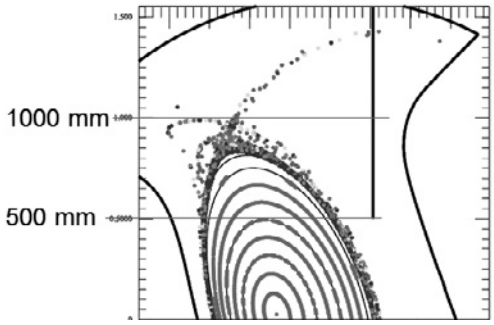

Fig. 1 Installation position of hybrid directional probe.

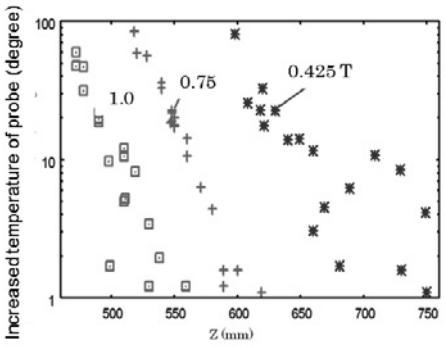

Fig. 2 the re-entering fast ions measured by using a hybrid directional probe.

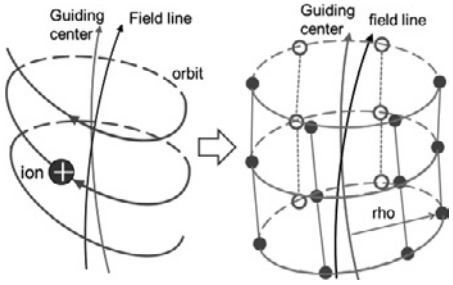

Fig. 3 Wall heat flux model of fast ions including the finite Larmor effect.

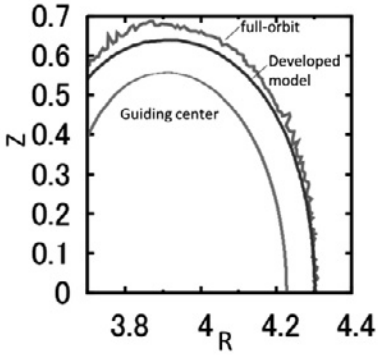

Fig. 4 Comparison of developed model with full-orbit calculation.