§6. Simulations of the Radial Profiles of Neutral Particle Density in Hydrogen and Helium Plasmas in the LHD

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The radial profile of neutral hydrogen/helium in pure hydrogen/helium plasmas are investigated using a neutral particle transport simulation code (EIRENE) with a fully three-dimensional grid model of a LHD geometry for R_{ax}=3.60m. In the simulation code, large amount of test particles representing neutral hydrogen atoms/molecules and helium atoms are released from the positions of the strike points on the divertor plates with an energy corresponding to the room temperature. By summing up the weight of the test particles passing each grids, the three-dimensional profiles of neutral densities are calculated.

For neutral hydrogen transport simulation in pure hydrogen plasma, the following eight atomic and molecular processes are included in the simulation:

$e + H \rightarrow e + H^+ + e$ (p1),
$H^+ + H \rightarrow H + H^+$ (p2),
$e + H_2 \rightarrow e + H_2^+ + e$ (p3),
$e + H_2 \rightarrow e + H + H$ (p4),
$e + H_2 \rightarrow e + H^+ + H + e$ (p5),
$e + H_2^+ \rightarrow e + H^+ + H$ (p6),
$e + H_2^+ \rightarrow e + H^+ + H^+ + e$ (p7),
$e + H_2^+ \rightarrow H + H$ (p8).

For neutral helium transport simulation in pure helium plasma, the following two situations are assumed. First one is purely singly ionized helium (He^+) plasma case, and the second one is purely doubly ionized helium (He^{++}) plasma case. In the first case, the following three atomic and molecular processes are considered in the simulation:

$e + He \rightarrow e + He^+ + e$ (p9),
$He^+ + He \rightarrow He^+ + He^+ + e$ (p10),
$He^+ + He \rightarrow He + He^+$ (p11).

In the second case, included atomic and molecular processes in the simulation are the following three ones:

$e + He \rightarrow e + He^+ + e$ (p12),
$He^{++} + He \rightarrow He^{++} + He^+ + e$ (p13),
$He^{++} + He \rightarrow He + He^{++}$ (p14).

Figure 1 is the observed radial profiles of the electron temperature T_e and the plasma density n_e which are used for the neutral hydrogen/helium transport simulations. Figure 2 indicates the calculated radial profile of neutral hydrogen atoms and molecules. Hydrogen atoms can penetrate deeply into the plasma due to the effect of the charge exchange (p2).

Figure 3 is the simulations in helium plasmas for the first and the second cases, showing that the penetration of the neutral helium in the peripheral plasma is weaker than that of the hydrogen atoms. The reason for this is that while the average penetration speed of the helium atoms corresponds to that of the room temperature (~0.026eV), the penetration speed of hydrogen atoms is based on the Franck-Condon energy (~3eV) produced by molecular dissociation (p3~p8). In addition, the charge exchange also contributes to the penetration of neutral particles. This is because low energy neutrals are changed to high energy neutrals. The cross-section of this process in hydrogen plasmas (p2) is larger than that in helium plasmas (p11, p14) by more than a factor of two in the range of ion temperatures in LHD.

In Figure 3, the density of the neutral helium in the plasma center is slightly reduced in the second (He^{++} plasma) case compared to that in the first case (He^+ plasma). The reason for this is that the cross-section of the charge exchange process in the second case (p14) is less than that s in the first case (p11) by more than a factor of two.

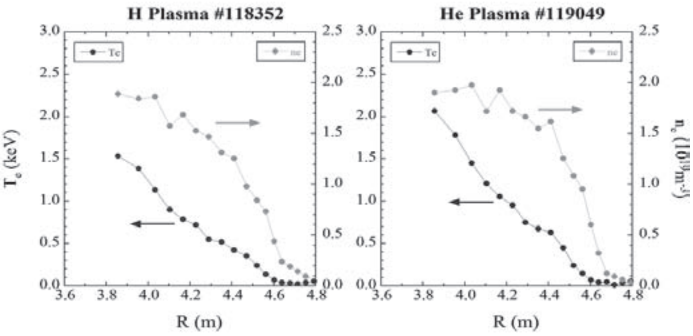

Fig. 1. The observed radial profiles of the electron temperature and the plasma density in pure hydrogen (left) and helium (right) plasmas for the simulation.

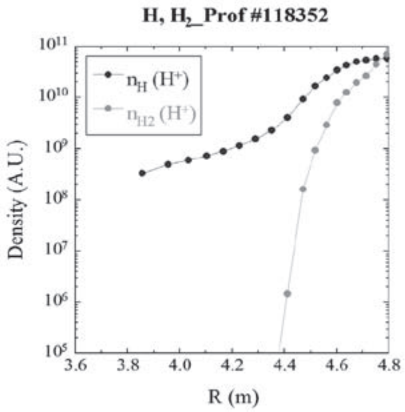

Fig. 2. Simulations of the radial profiles of the neutral hydrogen atoms and molecules in the pure hydrogen plasma case.

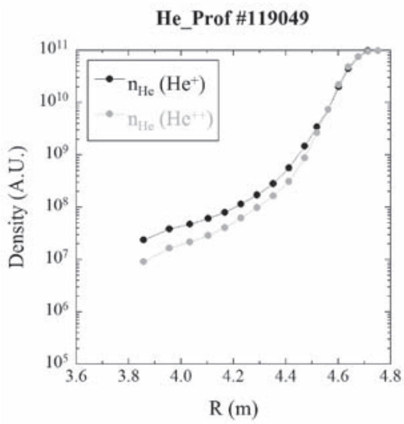

Fig. 3. Simulations of the radial profiles of the neutral helium atoms in the first (pure He^+) and the second (pure He^{++}) plasma cases.