§9. Comparison of Neutral Particle Flux Decay Times on the NBI Plasmas in Large Helical Device

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The decay times of the neutral flux can provide to understand the loss mechanism indirectly. Here we discuss them at the switching-off the heating on different NBI directions. Each beam is individually used instead of the beam modulation overlapped base plasma in order to obtain clear signals. The decay time consists of the classical atomic process and another loss mechanism. Therefore quick decay time may be due to additional loss mechanism.

In experiments, the NBI plasmas are created at the same magnetic axis and various magnetic fields. The neutral particle flux is observed by CNPA when the NBIs#1-4 are applied. NBI#1 and #3 have the same tangential direction. NBI#2 is also a tangential injection although it is different direction from NBI#1 and 3. NBI#4 is a perpendicular direction. Here we compare the neutral particle flux decay times when the co-, counter and perpendicular NBIs are applied at the magnetic axis of R_{ax}=3.65 m. In simulation, the chaotic region is minimized and the energetic particle is well confined at R_{ax} =3.65 m. The decay time of the neutral particle flux with a certain energy, which is originated from NBI, is determined by the electron drag (at the high energy region), the charge exchange loss (at the middle and low energy regions), the pitch angle dispersion (which is occurred in low energy region), and the orbit loss in the loss cone or chaotic region. Former three effects may be independent on the injection direction of NBI. Therefore if there is large discrepancy of the decay times between the tangential and perpendicular injections, the orbit loss is the most probable candidate of the loss mechanism.

Figure 1 shows the decay times in different magnetic field strength. Typical central electron density and temperature are 1-6 x 10^{19} m^{-3} and 1-3 keV at the plasma center, respectively. The difference between the beam directions can be found clearly. If the experimental parameters are chosen, the decay time is almost agreed with the energy loss time by the electron. This means the decay of the neutral particle is determined by the electron drag. When the magnetic field increases, the decay times in the tangential NBIs also increase. One candidate is that the electron temperature is high because the good particle confinement can be achieved in the high magnetic field. In the perpendicular NBI case, the decay time is from several ms to 10 ms. Here maximum injection energy is 40 keV. Therefore the ion-ion collision is essential for the energy relaxation and the pitch angle scattering. The neutral particle from the tangential NBI has uniform angular distribution when the particle injects to the CNPA. However we must be aware of the escape from the sight line because the sight line of CNPA is also perpendicular.

Figure 2 shows the comparison between the calculation of the energy loss time by the electron drag τ_{be} (strait lines) and the energy loss time by the ion-ion collision τ_d (broken lines) obtained from the calculation and the experimental results. The experimental data areas are shown by the rectangular in Fig. 2. In τ_{be} and τ_d, the experimental decay times both in the tangential and perpendicular NBIs are smaller than the calculated values. However it is not true that the most of particles are lost in the classical loss cone because the loss time should be several μs if there is a large loss cone. The particle loss from the classical loss cone or chaotic region is not so large especially in the high magnetic field.

We compare the decay times of charge exchange neutral particle fluxes in various NBI plasmas after switching-off NBI by using the Compact Neutral Particle Analyzer. Here the decay times at co-, counter and perpendicular injections are observed at the magnetic axis of R_{ax}=3.65. The decay times are determined mainly by the electron drag in tangential NBI. The decay time decreases by the weak magnetic field same as the simulation. The decay time at the perpendicular beam NBI is several – ten ms, which is less than one tens of that at the tangential injections. The decay time determined by the ion-ion collision, which is the main process of the energy loss and the pitch angle scattering at the injection energy of 40 keV, is about 10-20 ms. The observed decay times are still several times smaller than those values.

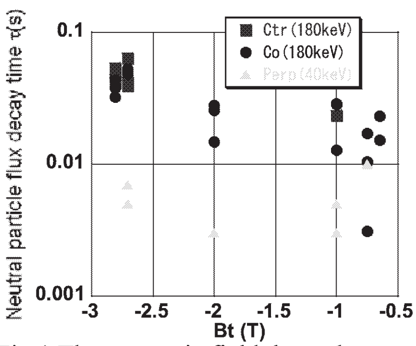

Fig.1 The magnetic field dependence of τ.

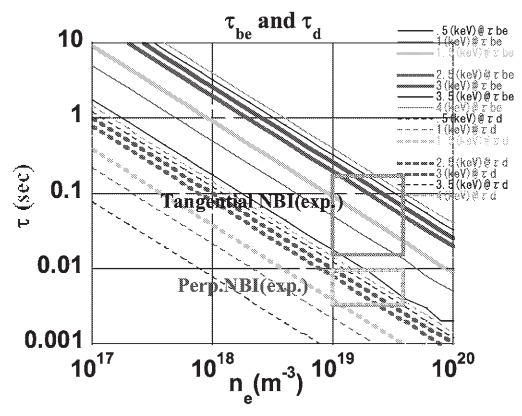

Fig.2 Comparison between calculation and experimental results.