§39. Evaluation of Deeply Trapped Fast-ion Confinement Using the NB-blip Experiments -II-

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The decay times of neutral flux after NB-short pulse injection are measured by Si-diode Fast Neutral Analyzers(FNAs) for three different configurations of LHD[1]. These decay times contain the information of lifetimes ($\tau_{\text{lifetime}}$) of fast-ions on the orbit and energy slowing-down times ($\tau_{\text{E}_{\text{inj}} \rightarrow \text{E}_{\text{decel}}}$) of them from the NB-injection energy to the threshold energy of the measurements, as shown below:

$$\frac{1}{\tau_{\text{decay}}} = \frac{1}{\tau_{E_{\text{inj}} \rightarrow E_{\text{decel}}} \left( \frac{E_{\text{inj}}^{3/2}}{E_{\text{decel}}^{3/2}} + \frac{E_{c}^{3/2}}{E_{\text{decel}}^{3/2}} \right)} + \frac{1}{\tau_{\text{lifetime}}} \quad (\text{---(1)})$$

where

$$\tau_{E_{\text{inj}} \rightarrow E_{\text{decel}}} = \frac{\tau_{\text{inj}}}{2} \ln \left( \frac{E_{\text{inj}}^{3/2}}{E_{\text{decel}}^{3/2}} + \frac{E_{c}^{3/2}}{E_{\text{decel}}^{3/2}} \right) \quad (\text{---(2)}).$$

The $E_{c}$ is the critical energy where the heating power to bulk electrons by fast-ions becomes equal to that to bulk ions. Using eq.(1), lifetimes of fast-ions are evaluated from the decay times and are compared to the 90-degree pitch angle scattering times and charge exchange loss times in Fig.1(a) and (b). As shown in these figures, the lifetimes are anti-correlating to the charge exchange loss times and are correlating with the 90-degree pitch angle scattering times. This suggests that the lifetime of fast-ions on the NPA sight lines are dominated by the pitch-angle scattering not by the charge exchange loss. Considering the fact that the pitch-angle resolution of the NPA is about 0.1 degree, the pitch-angle loss time from the sightline becomes much smaller value than the 90-degree pitch-angle scattering time and the value would be the order of mili-second. On the other hand, the measured lifetimes are order of 100-ms, this difference can be understood as follows. The lifetime is determined by the balance between the loss-rate from the NPA sight lines and incoming rate to it with the pitch angle scattering processes. If the fast-ions are lost significantly from the plasmas, the incoming rate to the sight line becomes small and the observed lifetime will be small. Therefore, the lifetime normalized by the 90-degree pitch angle scattering rate indicates the confinement property of fast-ions in LHD-plasmas. The dependence of normalized lifetimes, on the LHD configurations is shown in Fig.1(c). Fig.1(c) shows clearly the superiority of fast-ion confinement of inwardly shifted magnetic configurations to the outward ones.

![Fig. 1. The evaluated lifetimes of fast-ions are compared to (a) the orbit averaged 90-degree pitch angle scattering times($<\tau_{\text{perp}}>$) and (b) the charge exchange loss rate ($<\tau_{\text{ox}}>$). (c) The distribution of normalized lifetimes are shown for three different LHD configurations. The closed circles(●), open circles(○) and closed squares(■) indicates the LHD-configurations of Rax=3.6m, 3.75m and 3.9m, respectively.]

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