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

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The confinement properties of deeply trapped fast-ions are evaluated by the short pulse injection of radial-Neutral Beam(NB) injection on LHD. A typical wave-forms of fast-neutral flux which is measured by Si-diode FNA array[1] is shown for short-pulse injection by radial-NB in Fig.1(a). In this figure, the neutral flux whose energy is greater than 29keV are shown. The signal is decaying after the NB termination and its decay time (τ_{decay}) contains the information of energy slowing-down time($\tau_s^{Einj.\to Ethres.}$) and the particle life-time ($\tau_{lifetime}$) on the orbit as;

$$1/\tau_{decay} = 1/\tau_s^{E_{inj.}\to E_{thres.}} + 1/\tau_{lifetime} \quad \text{---(1),}$$

where
$$\tau_s^{E_{inj.}\to E_{thres.}} = \frac{\tau_{se}}{2}\ln\left(\frac{E_{inj.}^{3/2}+E_c^{3/2}}{E_{thres.}^{3/2}+E_c^{3/2}}\right) \quad \text{---(2).}$$

and $\tau_s^{Einj.\to Ethres.}$ is the slowing-down time of fast-ions from the NB-injection energy ($E_{inj.}$) to the threshold energy ($E_{thres.}$) of the measurement. The E_c is the critical energy where the heating power to bulk electrons by fast-ions becomes equal to that to bulk ions. Since the injected NBs are ionized all over along their injection path and the NPA is a line-integrated measurement, energetic particles produced by the beam experience various slowing-down times depending on their locations in a plasma before they are measured by the NPA as shown in Fig.1(b). So, if we set a certain delay time (t_{delay}) after the NB-injection in choosing the time range for e-hold fitting of neutral flux decay, we can localize the information of particle lifetime inside of its corresponding location in the orbit averaged normalized minor radius ($\langle r/a\rangle_{orbit}^{delay}$) since all of the fast-ions circulating outside of $\langle r/a\rangle_{orbit}^{delay}$ would slow-down its energy below $E_{thres.}$ and could not be detected after the delay time of t_{delay}. (Here, the symbol "$\langle\rangle_{orbit}$" express the average along the orbit). The fitting time range and its corresponding spatial location are shown by gray areas in Fig.1. In Fig.1(c), the fitted decay times are compared with the energy slowing time of the fast-ions. The location of the fast-ion orbits of our interests are identified to be $\langle r/a\rangle_{orbit}$=~0.6 and are obtained by averaging the values of gray area in Fig.1(b).. If the lifetimes of the fast-ions are infinite, the data points will be plotted around the line whose slope is unity. The deviations of the data points from the line are due to the finite values of the particle's lifetimes on their orbits, which are tangent to the NPA sight line.

[1] M.Isobe, to be published in Fusion Science and Technology.

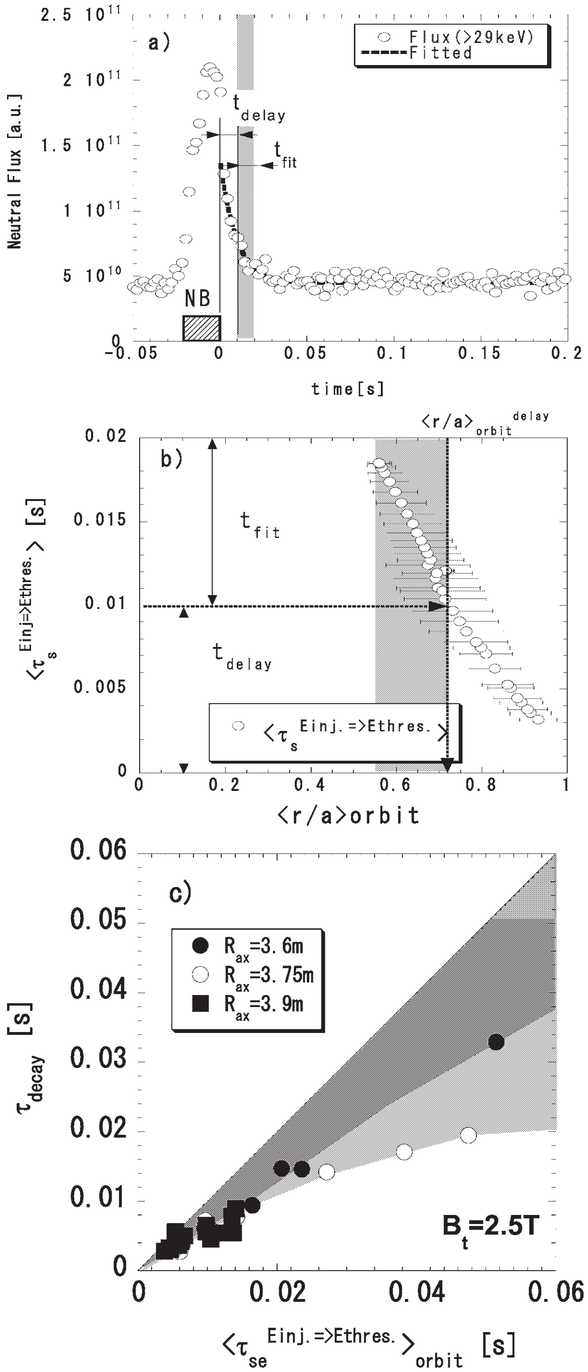

Fig. 1. (a)Typical waveform for fast neutral flux for NB short-pulse injection. The waveform is obtained by integrating the signals of #3 detector of SiFNA array at 5.5L-port. The shaded square at the bottom indicates the NB-injection period of 20ms. (b)Slowing-down time distributions of fast-ions from $E_{inj.}$ to $E_{thres.}$ on the sight line of SiFNA. A time delay (t_{delay}) for fitting region are shown with its corresponding spatial location in orbit averaged normalized minor radius ($\langle r/a\rangle_{orbit}^{delay}$). (c) The comparison of the decay time of neutral flux intensities to the energy slowing-down time. The closed circles(●), open circles(○) and closed squares(■) indicates the LHD-configurations of Rax=3.6m, 3.75m and 3.9m, respectively.