§2. Power Threshold for ETB Transition Based on NBI Power Deposition Calculation

Minami, T., Akiyama, T., Okamura, S., Nagaoka, K., Isobe, M.

The NBI power threshold for the ETB formation evaluated by the port-through value was reported in the last fiscal year. The threshold power is evaluated using the deposited NBI power. The deposited power is defined as follows,

$$P_{deposit} = P_{port} - P_{shine} - P_{orbit} - P_{cx} \qquad (1)$$

,where the $P_{deposit}$, the P_{port} and P_{shine} are the deposited, port-through and shine-through power, respectively. The P_{orbit} and P_{cx} is the orbit loss and the charge exchange loss during the slowing-down of injected beams, respectively. We use the following formula empirically obtained in the CHS experiments for estimating the deposited power.

$$P_{deposit} = P_{port} \times (1.0 - 2.35 \times 10^{-2} exp(-B_T)^{0.363} \times exp(-n_e)^{2.60} E_{nbi}^{1.35} (R_{ax} - 0.8)^{0.509} a^{-0.061}) \qquad (2)$$

,where $B_T(T)$ is the magnetic field strength at the magnetic axis, $n_e(\times 10^{14} cm^{-3})$ is the electron density, $E_{nbi}(kV)$ is the acceleration voltage of the NBI, $R_{ax}(m)$ is the major radius, and the $a(m)$ is the minor radius.

Figure 1 shows the delay time of the L-H transition from the second NBI injection for three experiments of the different days. The data are plotted as the function of deposited power normalized by the line-averaged electron density. All experiments are performed under the condition of B_T=0.95 T, R_{ax}=92.1cm. In the case of the 2003/6/19, the timing of the second NBI injection is delayed approximately 20ms after the first NBI injection, while the two NBIs are simultaneously injected in the other cases. Because the wall conditions of the three experiments and the NBI injection methods are various, the delay times for the three experiments are different. However, the delay times get longer when the normalized NBI power is close to the specific value of $200\times 10^{-13} kW/cm^{-3}$ for all the experiments, and the ETB is not formed below this specific threshold value. The value of the threshold power for the barrier formation is approximately two times as large as that expected from the tokamak H-mode scaling. When the delay times are plotted as a function of the NBI deposited power without being normalized , the data points are more scattered. The threshold for the formation of the ETB is determined by the averaged deposited power density, and accordingly the required NBI power for the transition increases as the density increases.

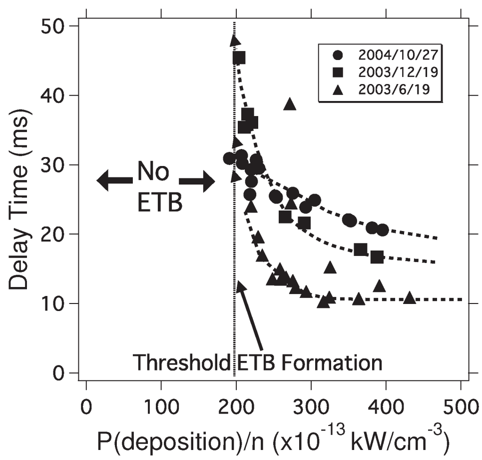

Fig. 1: **Delay time of L-H transition after NBI injection are plotted as a function of deposited NBI power normalized by electron density. Circles, triangles, and squares denote data in different experiments that have different wall conditions.**

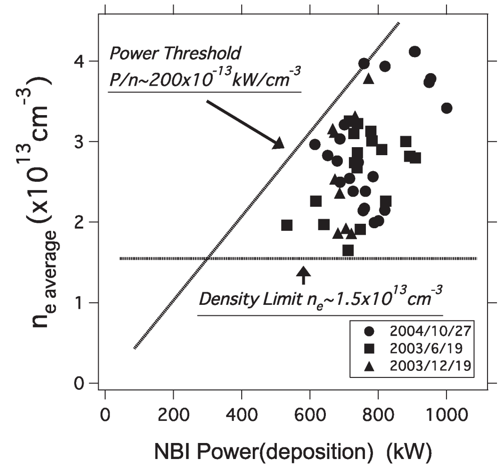

Fig. 2: **Averaged electron densities for plasmas with ETB are plotted as a function of deposited NBI power.**

We plot the average densities at the first drop of the H_α emission as the function of the injected powers. The figure 2 shows the ETB is formed when the deposited power exceed the $\sim 500kW$ at $n_e \sim 2 \times 10^{13} cm^{-3}$. The required power increases as the density increases as described above. In addition, the ETB formation has been observed when the plasma density exceeds $\sim 1.5 \times 10^{13} cm^{-3}$ with the gas-puffing, and the ETB has not been observed when the density is below the limit. The lower density limit increases as the deposited NBI power increases. These observations for the density limit are similar to the results in the WS-7AS experiments or the Heliotron J experiments.