Heating power dependence of the fusion triple product in high-density internal diffusion barrier plasmas in LHD

J. Miyazawa, R. Sakamoto, M. Kobayashi, H. Yamada, and LHD experimental group

National Institute for Fusion Science, 322-6 Oroshi, Toki, Gifu 509-5292, Japan

miyazawa@LHD.nifs.ac.jp

The fusion triple product, $n_{e0}\tau_E T_{e0}$, is one of the important indices for evaluating the performance of fusion plasmas, where n_{e0}, τ_E and T_{e0} are the central electron density, the energy confinement time and the central electron temperature, respectively. In this study, $n_{e0}\tau_E T_{e0}$ dependence on the heating power is investigated for high-density pellet-fuelled plasmas with steep density gradient named IDB (internal diffusion barrier) [1]. Conventional energy confinement scalings for helical plasmas, such as ISS95 [2] and ISS04 [3], are characterized by a so-called gyro-Bohm nature without no significant dependence on plasma beta and collisionality, *i.e.* $\tau_E^{GB} \propto \bar{n}_e^{\,0.6} P^{-0.6}$, where $\bar{n}_e$ is the line-averaged electron density and P is the total heating power. According to this, it is expected that $n_{e0}\tau_E T_{e0} \propto p_e \ \tau_E \propto (P \ \tau_E^{GB}) \ \tau_E^{GB} \propto \bar{n}_e^{\,1.2} P^{-0.2}$, as long as the profile of the electron pressure, p_e, is held. However, experimental results shown in Fig. 1 give stronger heating power dependence of $n_{e0}\tau_E T_{e0} \propto P^{-0.5}$, suggesting a loss of gyro-Bohm nature. This is occurring in the edge region called "mantle" [1], as seen in Fig. 2. The edge electron pressure p_{e08} at the effective normalized minor radius of $\rho_{eff} \sim 0.8$ is similar for the two discharges with more than 4 times different neutral beam heating power, P_{NB}, whereas the central electron pressure, p_{e0}, is approximately doubled for the higher heating power case. The results of regression analysis show that the gyro-Bohm nature is kept in the core region ($p_{e0} / P \propto \bar{n}_e^{\,0.54} P^{-0.65}$), while it is lost in the edge region ($p_{e08} / P \propto \bar{n}_e^{\,0.13} P^{-0.88}$).

[1] N. Ohyabu *et al.*, Phys. Rev. Lett. **97** (2006) 055002.
[2] U. Stroth *et al.*, Nucl. Fusion **36** (1996) 1063.
[3] H. Yamada *et al.*, Nucl. Fusion **45** (2005) 1684.

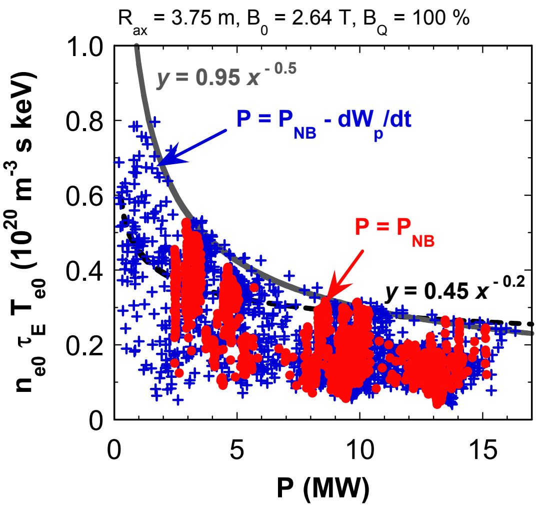

Fig. 1. The fusion triple product with respect to the heating power, $P = P_{NB}$ (red filled circles), or $P = P_{NB} - dW_p/dt$ (blue crosses). The upper envelope of the data suggests a strong power dependence of $P^{-0.5}$ as is shown by gray thick line. This is stronger than $P^{-0.2}$ (dashed line) expected from the gyro-Bohm model.

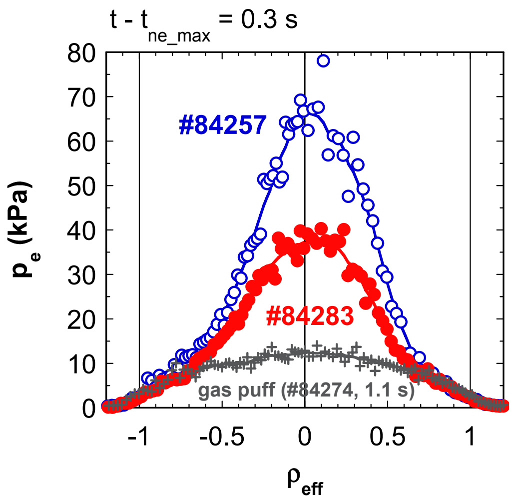

Fig. 2. Electron pressure profiles at similar density in pellet-fuelled IDB discharges with high heating power of P_{NB} = 14 MW (blue open circles), and low heating power of P_{NB} = 3 MW (red filled circles). Typical electron pressure profile in gas-fuelled discharge is also shown for comparison (gray crosses).