§5. Extension of High-beta Plasma Operation to low collisional Regime

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Previous experiments in LHD show that high beta plasma with more than 5% was successfully achieved in the high collisional regime because of low magnetic field operation at 0.425 T[1]. To investigate the collisionallity dependence of plasma confinement property, we have made high beta experiments in relatively high-field configurations at 1 T to increase the electron temperature. It is expected that the increase in the temperature raises magnetic Reynolds number, S, which contributes to suppression of low-n resistive interchange mode. Also recovery of plasma confinement is expected because plasma confinement in the high collisional regime (< 0.5 T) gradually decrease with beta value, which is predicted to be due to resistive-g turbulence with the same S dependence as the case of the low-n interchange mode. Also, relationship between collisionality and confinement property of high-beta plasma should be clarified from a viewpoint of characteristics of thermal /particle transport.

Figure 1 shows achieved beta value in different collisionality. In the previous high beta experiments, $\langle\beta\rangle$ of 5.1% was obtained in the plasmas with $\nu_h^* \sim 1000$ at 0.425 T. FY2014 experiments had been done at 1 T, and the optimum magnetic configuration for high-beta plasma production was explored. Consequently, $\langle\beta\rangle$ of 4.1% was achieved in the plasma with $T_{e0} \sim 0.9$ keV and $\nu_h^* \sim 100$ produced by the multi-pellet injections, and $\langle\beta\rangle \sim 3.4\%$ and $\nu_h^* \sim 20$ were realized by gas-puff. T_{e0} reached 1.2 keV then. In the $\langle\beta\rangle = 4.1\%$ discharge, peaked plasma pressure is formed after the pellet injection, which causes large Shafranov shift and core instability, whereas no confinement degradation is observed then.

The high-beta discharges with more than 3% due to the gas-puff fueling were realized by improvement of particle confinement in peripheral region of plasma. This improvement is unclear in the pellet discharge because of short duration of high beta state (< 0.1 s). Figure 2 shows typical gas-puff discharge with the "transition". The tangential NBIs produced and maintained the plasma from 3.3 s. The perpendicular NBIs and ICRF were additionally applied from 3.7 s. The electron density spontaneously increased at 3.8 s, which is due to the increment of peripheral electron density (we define this the transition here). The $\langle\beta\rangle$ reached 3.4% at 3.8 s, whereas it was limited by edge MHD instabilities (m/n = 1/2). When $\langle\beta\rangle$ spontaneously increases, ion saturation current on the divertor plate was largely reduced after the transition. The Hα started to decrease at 3.79 s as well as ion saturation current, and $\langle\beta\rangle$ started to increase at 3.8 s. The electron density and temperature on the divertor plate also decreased then.

The m/n = 2/3 and/or 1/2 modes excited in the plasma edge were enhanced after the transition, which limit the achieved beta value. According to HINT2 calculation, pressure profile was radially spread and the connection length was increased at R > 4.57 m after the transition. It suggests that enhancement of edge MHD instabilities are due to spontaneous appearance of rational surface with sufficiently long connection length, which means that magnetic field structure is changed from stochastic to nested one and it leads to the extension of plasma confinement region. One possibility is that the stochastic magnetic field formed by high-n magnetic islands is healed by effects of beta, collisionality and so on[2].

1) Sakakibara, S. et al.: Plasma Phys. Control. Fusion 50 (2008) 124014.
2) Sakakibara, S. et al.: Plasma Phys. Control. Fusion 55 (2013) 014014.

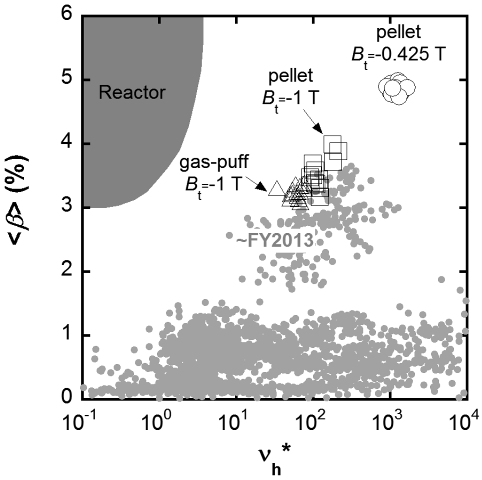

Fig. 1 Changes in achieved beta value as a function of collisionality.

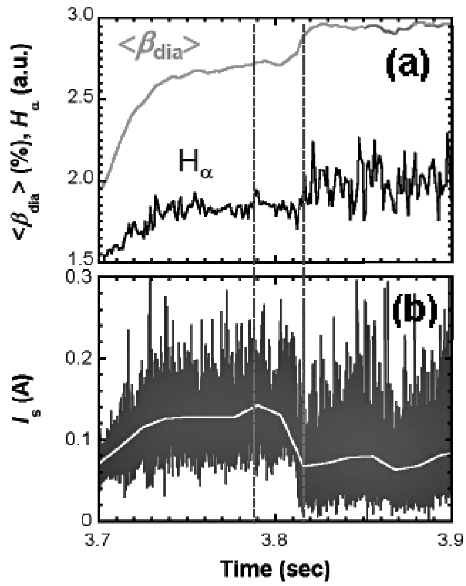

Fig. 2 Time evolutions of (a) averaged beta, Hα and (b) ion saturation current in the gas-puff discharge.