§1. Pellet Injection and Internal Diffusion Barrier Formation in LHD Plasmas

Sakamoto, R., Yamada, H.,
Confinement Improvement Experimental Group

An experimental study is performed to explore the operational space of a super dense core plasmas due to an internal diffusion barrier, which was originally found in pellet fueled high density discharges with the local island divertor configuration, in Large Helical Device (LHD). The internal diffusion barrier with steep gradient has been produced at an intrinsic helical divertor configuration in LHD by optimizing the pellet fueling and magnetic configuration.

Core fueling by multiple pellet injections is essential for the internal diffusion barrier formation. Nine-barrels in-situ pneumatic pipe-gun was employed to inject solid hydrogen pellets, which contain 1.5 - 2.0×10^{21} hydrogen atoms, at a velocity of ~1100 m/s every several 10 ms.

A grobal confinement property reach a maximun performance at an inward shifted magnetic configuration (R_{ax}= 3.65 m) which give a maximum plasma volume. The internal diffusion barrier, on the other hand, easily appears in the outward shifted magnetic configurations (R_{ax}> 3.75 m) in which magneto-hydrodynamic stability properties are considered to be favorable. Fig. 1 shows waveforms of the multi-pellet fueled high density discharges at different magnetic configurations (R_{ax}= 3.65 m, 3.75 m, 3.85 m). Timing of the final pellet injection is set as t=0. The Internal diffusion barrier is formed at R_{ax}= 3.75 m and above. While the same number of pellets were injected, attainable central plasma density becomes higher as the magnetic axis shifts outward. At the same time, central temperature follow an even process in spite of different magnetic configurations. As the result, high central pressure is easily attainable in the outward shifted magnetic configurations in which the internal diffusion barrier is formed. Comparison of plasma profiles of the super dense core plasma due to an internal diffusion barrier (R_{ax}= 3.75 m) and normal discharge plasma (R_{ax}= 3.65 m) are shown in fig. 2. The internal diffusion barrier with steep density gradient is formed on the inside of ρ= 0.6, and it can lead to high density regime while keeping temperature. A central pressure of the super dense core plasma increase with density and the central pressure exceeds atmospheric pressure. The super dense core plasma is, therefore, characterized by very large Shafranov shift (Δ/a_{eff} ~ 1/2), even at high magnetic field (B_t> 2.54 T).

The operational space of the super dense core plasmas are summarized in fig. 3. Maximum central density reaches 1×10^{21} m^{-3} just after pellet injection at R_{ax}= 3.9 m and above. Central pressure reach its greatest value at the neighborhood of R_{ax}= 3.85 m. The maximum central pressure is limited by an core density collapse (CDC) event as shown in fig. 1 at t= 0.19 s in the case of R_{ax}= 3.85 m. The CDC event is typically observed in the high performance discharges with the internal diffusion barrier and it may be involved with MHD equilibrium arising from very large Shafranov shift. The CDC event can be suppressed by controlling ellipticity of the magnetic configuration.

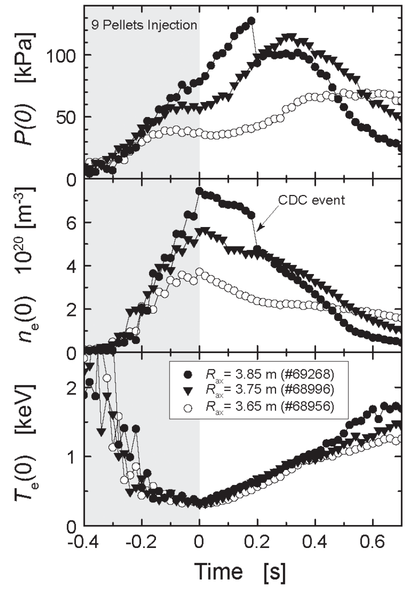

Fig. 1 Waveforms of the multi-pellet fueled high density discharges.

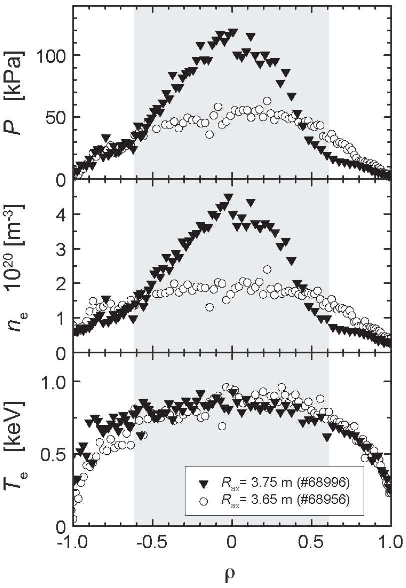

Fig. 2 Comparison of plasma profiles of the super dense core plasma due to an internal diffusion barrier (R_{ax}= 3.75 m) and normal discharge plasma (R_{ax}= 3.65 m).

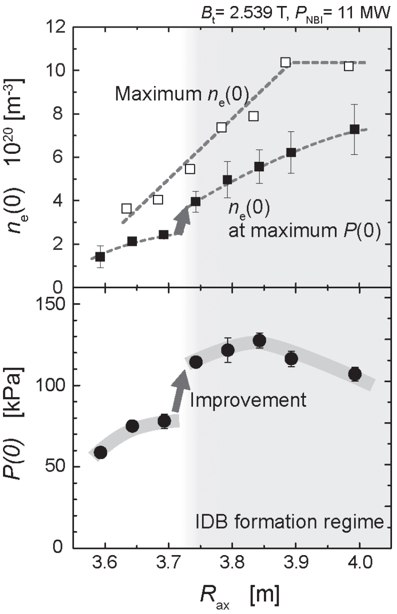

Fig. 3 Operational space of the super dense core plasmas due to Internal diffusion barrier.