§3. Optimization of Magnetic Configuration for the High Fusion Triple Product Operation

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High fusion triple product of $n_{e0}\tau_E T_{e0} \sim 0.5 \times 10^{20}$ m^{-3} s keV, where n_{e0}, τ_E and T_{e0} are the central electron density, the energy confinement time, and the central electron temperature, respectively, has been achieved after finding of the high-density internal diffusion barrier (IDB) plasmas in LHD.[1)] There is an optimum magnetic configuration for $n_{e0}\tau_E T_{e0} = p_{e0}\tau_E$, where $p_{e0} = n_{e0}T_{e0}$ is the central electron pressure, because of the opposite magnetic configuration dependence of p_{e0} and τ_E.

Contrastive to the strong magnetic configuration dependence of the global energy confinement property in LHD, p_{e0} in pellet-fuelled plasmas including IDB plasmas increases with the central density in a similar manner at various magnetic configurations of R_{ax} = 3.60 – 3.80 m as is shown in Fig. 1, where R_{ax} is the major radius of the magnetic axis in the vacuum condition. Nevertheless, the upper envelope of Fig. 1 suggests gyro-Bohm like density dependence of the pressure, *i.e.*, $p_{e0} \propto n_{e0}^{0.6}$, as is also observed for τ_E.

R_{ax} dependence of pellet-fuelled plasmas is summarized in Fig. 2, where the magnetic field strength and the heating power are fixed while the pellet injection scheme is optimized at each configuration. n_{e0} and p_{e0} increase as R_{ax} is shifted outward, while τ_E monotonically decreases with increasing R_{ax}. In the case of Fig. 2, the optimum R_{ax} for high $n_{e0}\tau_E T_{e0}$ is 3.75 – 3.80 m.

To achieve high $n_{e0}\tau_E T_{e0}$, it is effective to reduce the heating power after the IDB formation, which we call "annealing operation" on the analogy of metallurgy.[1)] $n_{e0}\tau_E$ in various configurations is plotted as a function of T_{e0} in Fig. 3. The annealing operation has been carried out at R_{ax} = 3.70, 3.75, and 3.80 m. High $n_{e0}\tau_E T_{e0}$ of ~ 0.5×10^{20} m^{-3} s keV has been achieved in these configurations around R_{ax} ~ 3.75 m, which are the optimum for high $n_{e0}\tau_E T_{e0}$ as expected from the opposite tendency of p_{e0} and τ_E.

1) Miyazawa, J., et al.: Ann. Rep. NIFS Apr. 2007 – Mar. 2008 (2008) 8

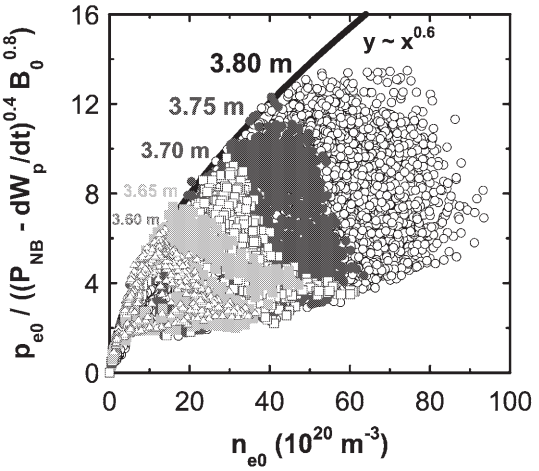

Fig. 1. n_{e0} dependence of p_{e0} normalized by the gyro-Bohm type parameter dependence in pellet-fuelled plasmas. The upper envelope suggests no or weak configuration dependence of p_{e0}, while the gyro-Bohm property is maintained.

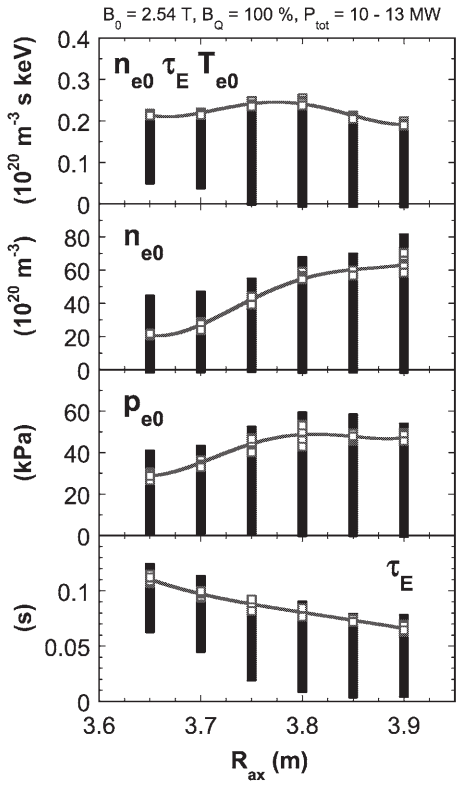

Fig. 2. Magnetic configuration dependence of $n_{e0}\tau_E T_{e0}$. The magnetic field strength of 2.54 T and the NB heating power of 10 – 13 MW are fixed. Open squares denote the subset of high $n_{e0}\tau_E T_{e0}$.

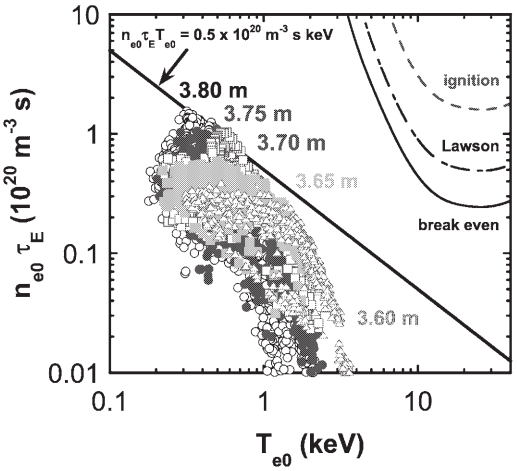

Fig. 3. T_{e0} dependence of $n_{e0}\tau_E$ in various magnetic configurations. Important milestones to the fusion reactor of the break even condition, the Lawson condition, and the ignition condition are also depicted.