§6. Formularization of the Confinement Enhancement Factor as a Function of the Heating Profile

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The confinement enhancement factor, γ_{DPE}, used in the Direct Profile Extrapolation (DPE) method [1] has been formularized using the peaking factor of the neutral beam (NB) heat deposition profile, $(P_{dep}/P_{dep1})_{avg}$, which is the line-average of (P_{dep}/P_{dep1}) inside $\rho \le 1$, and

$$P_{dep}(\rho^*) = \int_0^{\rho^*} P'_{dep} (\mathrm{d}V/\mathrm{d}\rho)_{exp} \mathrm{d}\rho. \qquad (1)$$

$P_{dep1} = P_{dep}(1) = P_{exp}$ is the total NB heating power.

In the DPE method, the gyro-Bohm normalized electron pressure profile is defined by $p_{e,exp}(\rho)/(a_{exp}^{2.4} R_{exp}^{0.5} P_{exp}^{0.4} B_{exp}^{0.8} n_{e,exp}(\rho)^{0.6})$. This can be fitted by the zero-order Bessel function of $\alpha_0 J_0(2.4\rho/\alpha_1)$, or $\alpha_{0*} J_0(2.4\rho/\alpha_{1*})$, as shown in Fig. 1, where all profile data are used to obtain α_0 and α_1 (thin solid lines in Fig. 1), while the profile data in the outer region of $0.5 < \rho \le 1$ are used to obtain α_{0*} and α_{1*} (bold broken lines in Fig. 1). In LHD, the pressure profile occasionally shows flattening in the core region as shown in Fig. 1(a). This is what we call the *core confinement degradation*. The physics mechanism of this is not understood yet. The latter model with α_{0*} and α_{1*} has been introduced to estimate the core pressure profile from the data in the outer region of $0.5 < \rho \le 1$ in the case with the core confinement degradation.

In Fig. 2, shown are the dependences of the plasma parameters on the line-averaged electron density, $\bar{n}_e$. The magnetic stored energy, W_p, that shows the gyro-Bohm type density dependence ($W_p \propto \bar{n}_e^{0.6}$) often degrades at high-density. This is called the *global confinement degradation*, and is clearly observed in the plasmas fuelled by gas puffing (GP). In the plasmas fuelled by hydrogen ice-pellet injection (PI), the gyro-Bohm type density dependence is kept even in the high-density regime reaching 10^{20} m^{-3}. However, the value is slightly smaller than that expected from low-density GP data (Fig. 2(a)). This global degradation is related to the heating profile that changes from centrally peaked to flat to hollow as the density increases (Fig. 2(d)) and the NB penetration length becomes shallow.

Regression analysis using over 800 profile data gives a relation of $\alpha_{0*} \propto (P_{dep}/P_{dep1})_{avg}^{0.61}$. If we assume for FFHR-d1 that 1) the core confinement degradation can be avoided, 2) the global confinement is proportional to α_{0*}, and 3) the peaking factor of the alpha heat deposition profile is 0.65, then γ_{DPE} is given by

$$\gamma_{DPE} = (0.65 \ / \ (P_{dep}/P_{dep1})_{avg})^{0.6}. \qquad (2)$$

1) J. Miyazawa, et al., Fusion Eng. Des. **86** (2011) 2879.

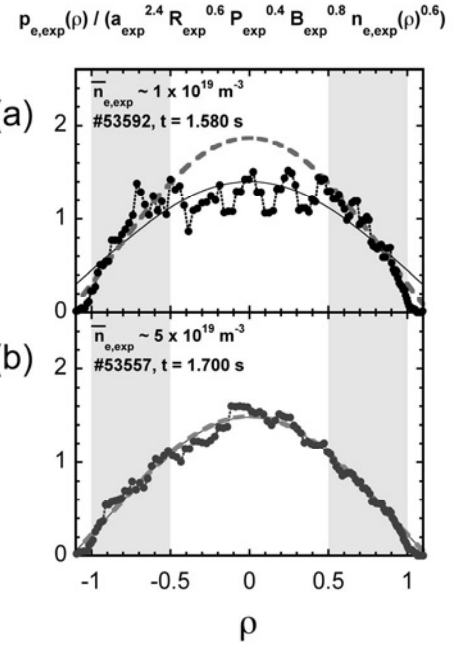

Fig. 1. Gyro-Bohm normalized electron pressure profiles at various line-averaged electron densities of (a) ~1 × 10^{19} m^{-3} and (b) ~5 × 10^{19} m^{-3}. The thin solid curve and the bold broken curve in each figure correspond to the fitting models of $\alpha_0 J_0(2.4\rho/\alpha_1)$ and $\alpha_{0*} J_0(2.4\rho/\alpha_{1*})$, respectively. The data in the shaded region of $0.5 < \rho < 1.0$ are used to estimate α_{0*} and α_{1*}.

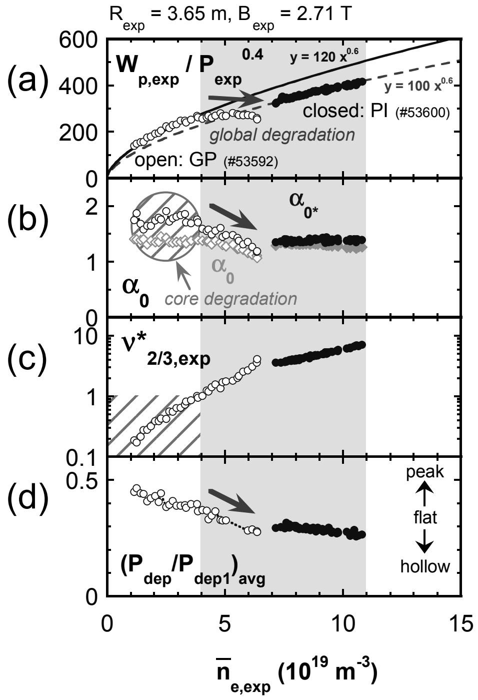

Fig. 2. Density dependence of (a) the plasma stored energy, W_p, normalized by $P_{exp}^{0.4}$, (b) the height of the gyro-Bohm normalized electron pressure profile, α_0 and α_{0*}, (c) the collisionality, $\nu^*_{2/3,exp}$, at $\rho = 2/3$, and (d) the peaking factor of the NB heat deposition profile, $(P_{dep}/P_{dep1})_{avg}$.