24C11

Impact of T_e/T_i on confinement properties with emphasis on profile shapes

T_e/T_iの閉じ込め性能に対する寄与と分布形状効果に関する研究

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In order to know the impact of the temperature ratio T_e/T_i on confinement properties, the updated DB3v10 database has been analyzed It is suggested that the increasing in T_e/T_i deteriorates the confinement in peaked density regime. This result has been checked against the simulation for JT-60SA using the transport code TOPICS with the GLF23 transport model module and the GS2 code. As a consequence, these results qualitatively agree with each other.

1. Introduction

The IPB98(y,2) scaling law[1], which has been widely used for predicting the performance of future devices, was elaborated from largely consists of dominantly ion-heated discharges. In a future burning machine, like ITER, on the contrary, it is expected that T_e/T_i is larger than unity due to the strong alpha heating. In order to understand the impact of T_e/T_i on confinement properties, we have studied the updated DB3v10 database[1,2], with emphasis on the T_e/T_i effect. The impact has been also investigated by using the transport code TOPICS[3] with GLF23 transport model module and the code GS2[4].

2. Scaling analyses with emphasis on the T_e/T_i

The 317 data from JET, 67 from AUG and 68 from C-Mod have been extracted from the database. For these data, the central temperature ratio T_{e0}/T_{i0} is limited in the range 0.5< T_{e0}/T_{i0}<1.5, the peaking factor, which is defined as the ratio of central density and line averaged density, is limited in the range $1.0<n_{e0}/n_e<1.6$, and the line averaged density is lower than 60% of n_{GW}. As a consequence of regression analyses, we have obtained following scaling expressions in two peaking factor regimes;

$$\tau_{sc1} = 0.0777 I_p^{0.91} B_t^{0.11} n_e^{0.28} P_L^{-0.59} R^{1.73} M^{0.27} \varepsilon^{0.54} \kappa^{0.41},$$
; $1.0<n_{e0}/n_e<1.1$ (flat density case), (1)

$$\tau_{sc2} = 0.0594 I_p^{0.90} B_t^{0.08} n_e^{0.34} P_L^{-0.63} R^{1.78} M^{0.16} \varepsilon^{0.41} \kappa^{0.72},$$
; $1.1<n_{e0}/n_e<1.6$ (peaked density case). (2)

The notations comply with conventional definitions. Histograms of τ_{th}/τ_{sc1} and τ_{th}/τ_{sc2} for $T_{e0}/T_{i0}<1$ and $T_{e0}/T_{i0}>1$ are shown in Fig.1. Fig.1(a) and (c) describe that the peaked density profile improves the confinement for discharges with $T_{e0}/T_{i0}<1$, whereas, it works adversely in the $T_{e0}/T_{i0}>1$ case.

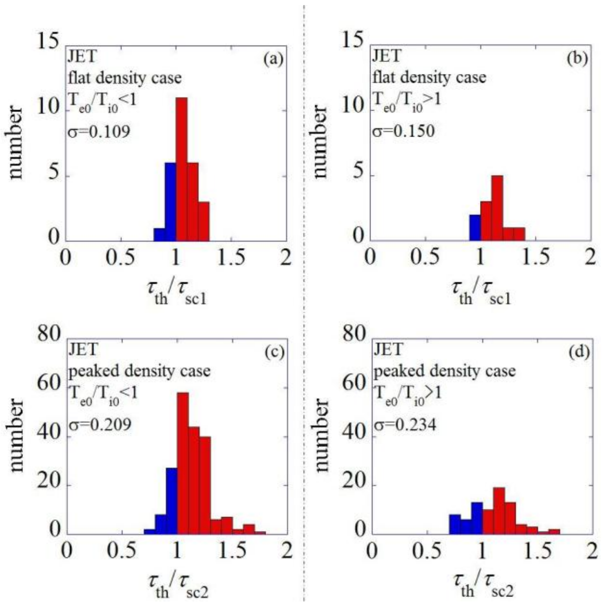

Fig.1. Histograms τ_{th}/τ_{sc1} and τ_{th}/τ_{sc2}. (a) and (b) flat density case, (c) and (d) peaked density case. $T_{e0}/T_{i0}<1$ data are shown in (a) and (c). $T_{e0}/T_{i0}>1$data are shown in (b) and (d).

For the latter, we have further developed a scaling expression including T_e/T_i for peaked density case. We incorporated 3 nondimensional variables[5], namely $B_t R^{1.25}$, n_e/n_{GW}*, and q in addition to T_e/T_i.

Here, n_e/n_{GW}* is dimensionless normalized density. The dependences on n_e/n_{GW}* and q were weak, and the following new expression was obtained; which reduce the standard deviation remarkably,

$$\tau_{sc3} = \tau_{sc2}\{1\text{-}0.157(T_{e0}/T_{i0}\text{-}1)(B_tR^{1.25})^{0.59}\}. \qquad (3)$$

Here, we find that the confinement time decreases with increasing T_{e0}/T_{i0}[6]. The correction term f=0.157(T_{e0}/T_{i0}-1)($B_tR^{1.25}$)$^{0.59}$ in (3) was plotted against n_{e0}/n_e for large and small values of T_{e0}/T_{i0}. It is deduced that peaked density profiles contribute to an improvement for low value of T_{e0}/T_{i0} region and deteriorate for high value of the ratio region.

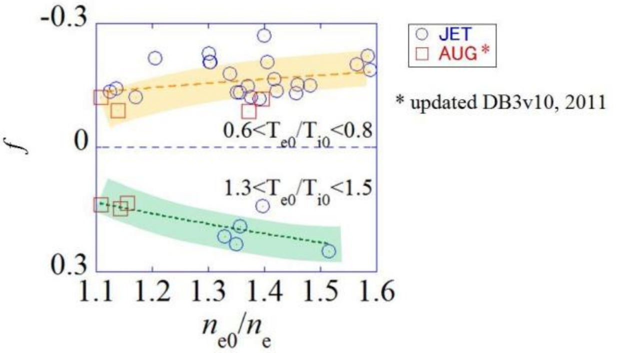

Fig. 2. Dependence of the correction term f in (3) on peaking factor n_{e0}/n_e for large and small values of temperature ratio.

3. Simulations with GLF23 and GS2

The impact of T_e/T_i on confinement with emphasis on the density profile is demonstrated by simulations using the transport code TOPICS with the GLF23 transport model module and using the code GS2. GLF module suggests that the transport is enhanced for large T_e/T_i regime[7], and the code GS2 is effective to investigate the low-frequency turbulence in magnetized plasmas.

We investigated the effect of T_{e0}/T_{i0} in four types of density profiles using TOPICS with GLF23. The value of T_{e0}/T_{i0} is varied by the ratio between heating power for electrons and that for ions. The effects of α stabilization and ExB shear stabilization are included in these simulations. Fig. 3(a) shows the dependence of H_H-factor on T_{e0}/T_{i0} for different density profiles. Here, H_H-factor is defined as $H_H=\tau_{th}/\tau_{IPB98(y,2)}$. The dependence of derivative value of H_H-factor with respect to T_{e0}/T_{i0} as a function of peaking factor is demonstrated in Fig.3(b). The effect of T_{e0}/T_{i0} becomes more profound with the increasing of peaking factor. This agrees with the results from scaling analyses.

The influences of T_{e0}/T_{i0} and n_{e0}/n_e have also been investigated with the GS2 code. Fig. 4

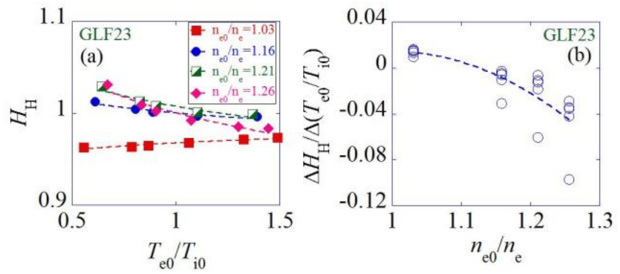

Fig. 3. (a) Dependence of H_H-factor on T_{e0}/T_{i0} for different density profiles. (b) Derivatives of H_H-factor for T_{e0}/T_{i0} against the density peaking factor. Here, $I_p \approx 2.3$MA, $B_t \approx 1.7$T, $q_{95} \approx 4.7$, $\kappa \approx 1.9$ and $\delta \approx 0.49$.

indicates increased linear growth rate and larger amplitude of potential fluctuation at larger T_{e0}/T_{i0} in higher normalized wave number. Fig. 4(a) also shows that the effect of T_{e0}/T_{i0} on linear growth rate is slightly higher in the peaked density profile at larger T_{e0}/T_{i0}, and Fig. 4(b) shows that the effect on energy flux is stronger in the peaked density profile. These impacts of T_{e0}/T_{i0} and n_{e0}/n_e are consistent with results of the database analyses.

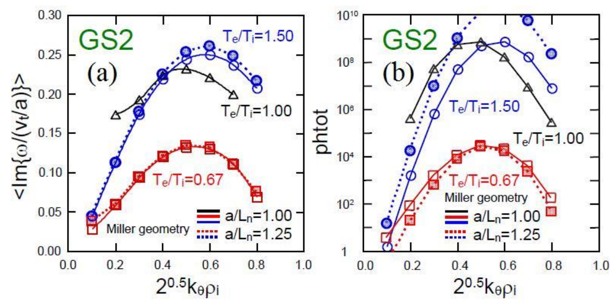

Fig. 4. Dependences of (a) growth rate and (b) amplitude of potential fluctuation on normalized wave number. Here, $q_{95} \approx 3.03$, $\kappa \approx 1.66$ and $\delta \approx 0.429$.

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