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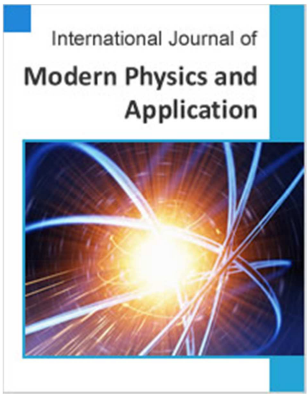

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Electron Heating Edge Transport Barrier in Small Size Divertor Tokamak

Amr Hasheim Bekheit

Plasma & Nuclear Fusion Department, Nuclear Research Center, Atomic Energy Authority, Cairo, Egypt

Email address

amrhasheim@yahoo.com

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Abstract

Most of the analysis of Edge Transport Barriers (ETB) in small size divertor tokamak so far concentrated on the regime with dominant ion heating, i.e with ($T_i > T_e$). As rector conditions are characterized by dominant electron heating, and consequently ($T_i \leq T_e$). The Edge Transport Barrier in the regime with dominant electron heating, ($T_i \leq T_e$) can be simulated by using B2SOLPS5.0 2D multifluid transport code. The results of simulation demonstrated the following: (1) In a small size divetor tokamak in regime with dominant electron heating, ($T_i \leq T_e$) have a strong effect on plasma density. (2) Regime dominant with electron heating, ($T_i \leq T_e$) has a strong influence on Ion Edge Transport Barriers (IETB). (3) The depth of the radial electric field well in the regime with dominant by electron heating, ($T_i \leq T_e$) is greater than the depth of the radial electric field in the regime dominated by coupling electron and ion heating ($T_e = T_i$). Within this framework, deeper 'E_r' wells provide stronger radial field shear, which increased the capacity for turbulence suppression, leading to improved plasma confinement. Also the depth of the radial electric field is a function of electron temperature. (4) A direct comparison of the pressure characteristic scale length 'L_P' and stability parameter 'η_e' shows very little change in response to regime dominant with electron heating, ($T_i \leq T_e$). This provides additional evidence for strong edge pressure profiles in 'ETB' and there appears to be significant 'η_e' constraint. Due to the coupling of characteristic lengths of electron temperature and plasma density via 'η_e' = $0.006|_{T_i \leq T_e}$, the profile inside 'ETB' can be specified by the limit on 'L_P'. (5) Lowing the plasma line density results in an elevated the stability parameter 'η_e' and effectively shifting of plasma density outboard.

1. Introduction

The edge plasma plays a key role in regulating the confinement properties of tokamak discharges, due to strong sensitivity of core transport to edge boundary conditions, as suggested by both experimental and computational results [1-4]. The ETBs have been formed in large numbers of tokamaks by using different methods (neutral beam injection NBI, electron cyclotron heating, ion cyclotron frequencies (ICRF) heating, etc.) and have been observed in both electron and ion channels. In particular the high confinement-mode (H-mode) regime [5] is the result of increased density and temperature gradients, in edge profiles and producing greater energy confinement than low confinement modes (L-mode). Most ETBs in small size divertor tokamak are produced at relatively low density ($\leq$(1-3) $\times 10^{19}$ m^{-3}), in regime dominated with coupling electrons and ions $T_e = T_i$. Most of ETB's are also generated by substantial external momentum input from neutral beam injection NBI. In this article, the 'ETB' which created in the edge plasma of small size divertor tokamak in the regime dominant with electron heating, ($T_i \leq T_e$) is simulated by *B2SOLPS5.02D multifluid transport code* [6-7]. The simulation provides that, the depth of the radial electric field well in regimes with dominant by electron heating is greater than the depth of the radial electric field in the regime dominated by coupling electron and ion heating $T_e = T_i$. Within this framework, deeper 'E_r' wells provide stronger radial field shear, which increased capacity for turbulence suppression, leading to improved plasma confinement. Also the depth of the radial electric field is a function of electron temperature.

2. The Main Results of Simulation

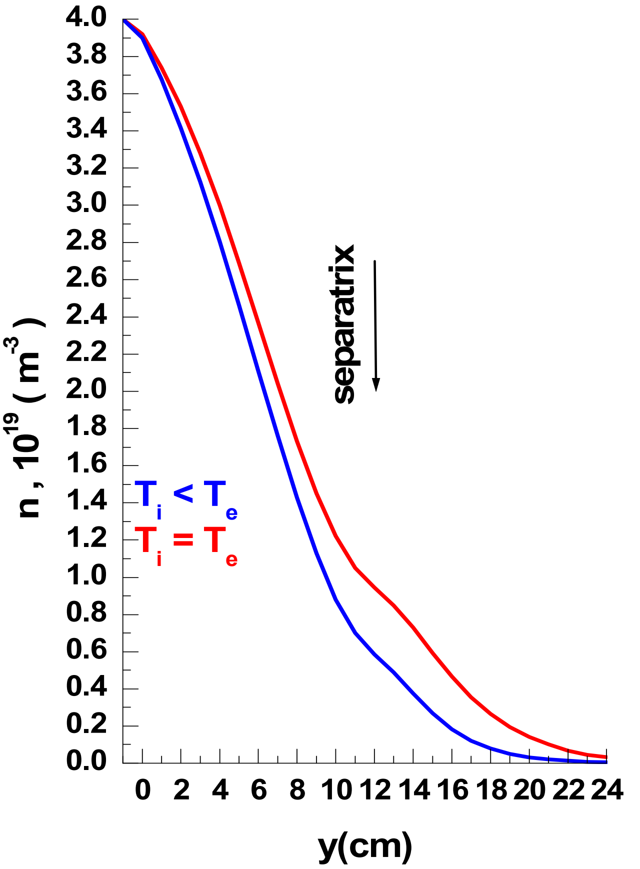


Figure 1. *Radial distribution of plasma density in the regimes with domination electron heating ($T_i \leq T_e$) and couples electron and ion heating ($T_e = T_i$).*

B2SOLPS5.02D multifluid transport code [6-7] has been used to analyze electron heating, ($T_i \leq T_e$) edge transport barriers in small size divertor tokamak with 50*KA* plasma current, and toroidal magnetic field of 1.7 *T* (ion ∇B drift is toward the active X-point). Plasma equations of B2SOLPS5.02D are dependent on the Bragnskii [8], but cross-field velocities are analytic with parameterized turbulent transport. Impurity effects were ignored in this simulation, improving computational tractability. In this simulation, density at the core boundary is as follows: 4×10^{19} m^{-3}. Simulation is done in the case of the regime dominated with electron heating, ($T_i \leq T_e$). The anomalous values of diffusion and heat conductivity coefficients were chosen: $D = 0.01 m^2 s^{-1}$ and $\chi_{e\text{-}i} = 0.7\ m^2 s^{-1}$. The results of simulation are:

The first result of simulation shows that, the radial profile of plasma density in small size divertor tokamak in regime with domination of electron heating ($T_i \leq T_e$) as showed in figure 1. In figure 1 showing that, there is a clear formation of strong ETB in the regime of domination of electron heating ($T_i \leq T_e$). The plasma density in the regime domination ($T_i \leq T_e$) is slightly higher than the plasma density in the regime with couples electron and ion heating ($T_e = T_i$) and shift inboard as showed in figure 1. From this result, we conclude that, in small size divertor tokamak concentrated on regimes with domination electron heating ($T_i \leq T_e$) has a strong effect on plasma density 'ETB'.

The Second Result of Simulation shows that, the radial profile of ion temperature on the regimes with domination electron heating ($T_i \leq T_e$) and couples electron and ion heating ($T_e = T_i$) are shown in figure 2. Figure 2 showing that, there is a clear Ion Edge Transport Barrier (IETB), which slowly move outward in a radial direction for a regime with domination electron heating ($T_i \leq T_e$). From this result, we conclude that regimes with domination electron heating ($T_i \leq T_e$) have a strong influence on the ion edge transport barrier.

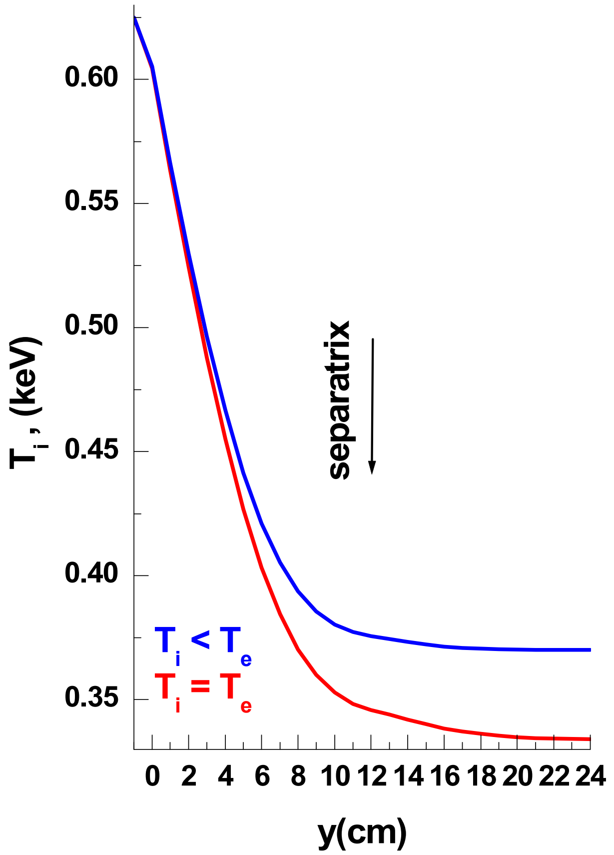


Figure 2. *Radial distribution of ion temperature in the regimes with domination electron heating, ($T_i \leq T_e$) and couples electron and ion heating ($T_e = T_i$).*

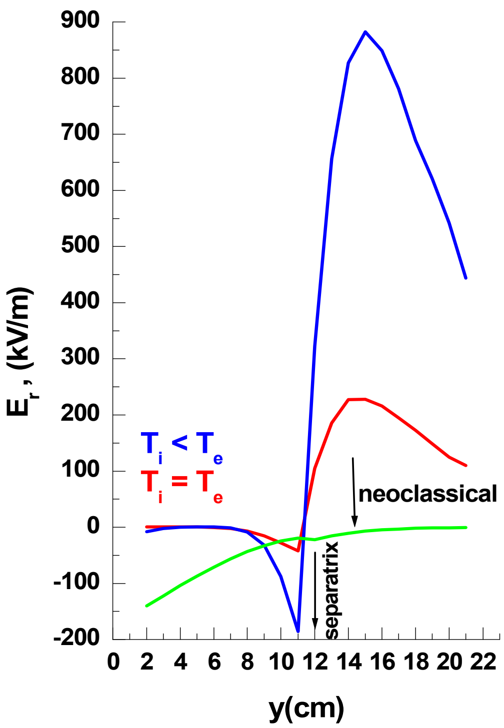


Figure 3. *Radial distribution of radial electric field in the regimes with domination electron heating, ($T_i \le T_e$) and couples electron and ion heating ($T_e = T_i$).*

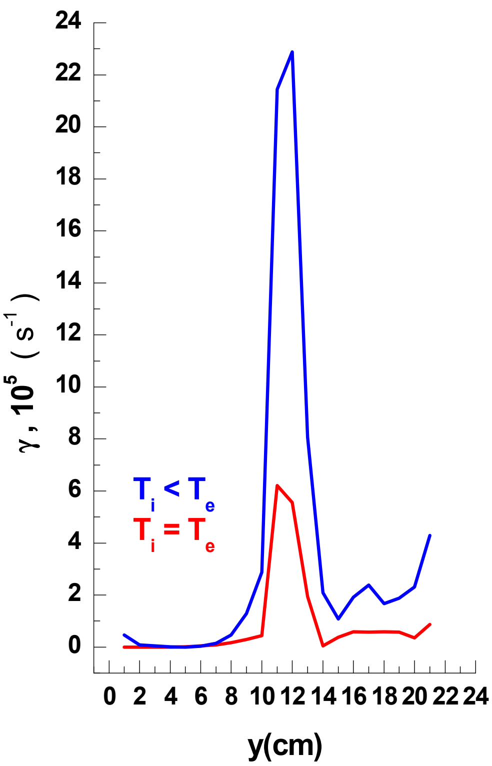
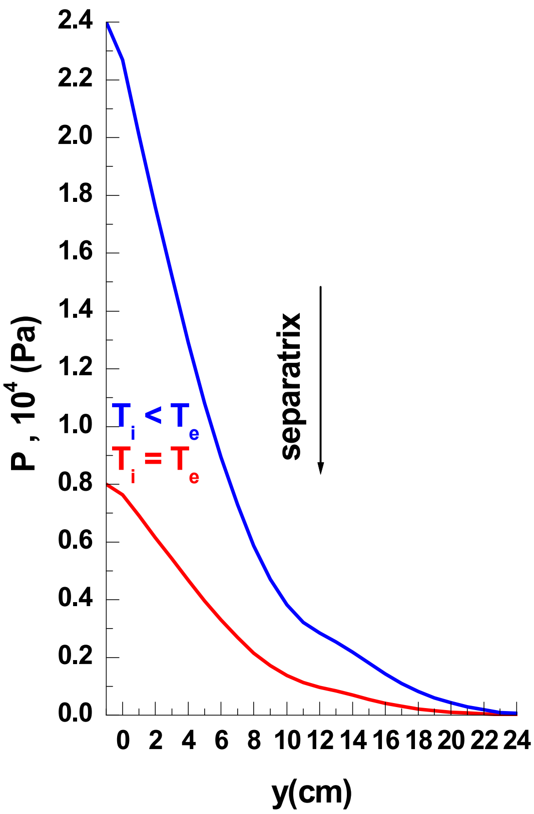


Figure 4. *Radial distribution of radial electric field shear in the regimes with domination electron heating ($T_i \le T_e$) and couples electron and ion heating ($T_e = T_i$).*

The Third Result of Simulation shows that, the radial electric field profiles on regimes with domination electron heating ($T_i \le T_e$) and couples electron and ion heating ($T_e = T_i$) are shown in figure 3. During 'ETB' phase, the radial electric field at regimes with domination electron heating and couples electron and ion heating ($T_e = T_i$) is close to the neoclassical radial electric field given by [6-7], with the exception a deep negative well in the separatrix vicinity. The negative well of 'E_r' on the core side of the computational domain is determined by the balance between negative contribution from plasma and ion temperature gradient first term of the neoclassical radial electric field equation given by [6-7] and positive contribution from co-current (negative) toroidal rotational second term of this equation. However, it should be noted that the depth of the 'E_r' well is (-186*KV/m*) deep for a regime with domination by electron heating ($T_i \le T_e$), although well as (-42.2 *KV/m*) for a regime with couples electron and ion heating ($T_i = T_e$) has been observed in figure 3. Also figure 3 show that, the depth of the radial electric field is also correlated with electron temperature. We conclude there is a strong correlation between, the 'E_r' well depth and electron temperature. The relation between the depth of radial electric and radial electric field shear has been explored and a clear correction found deeper radial electric field wells and radial electric field shear. This correlation is shown in figure 4 and is keeping with the paradigm of radial electric field shear suppression as the mechanism by which H-mode confinement is achieved within this framework, deeper 'E_r' wells provide stronger radial electric shear, which increased capacity for turbulence suppression, leading to improved plasma confinement.



Fiureg 5. *Radial distribution of kinetic pressure in the regimes with domination electron heating, ($T_i \le T_e$) and couples ion-electron heating edge ($T_i = T_e$).*

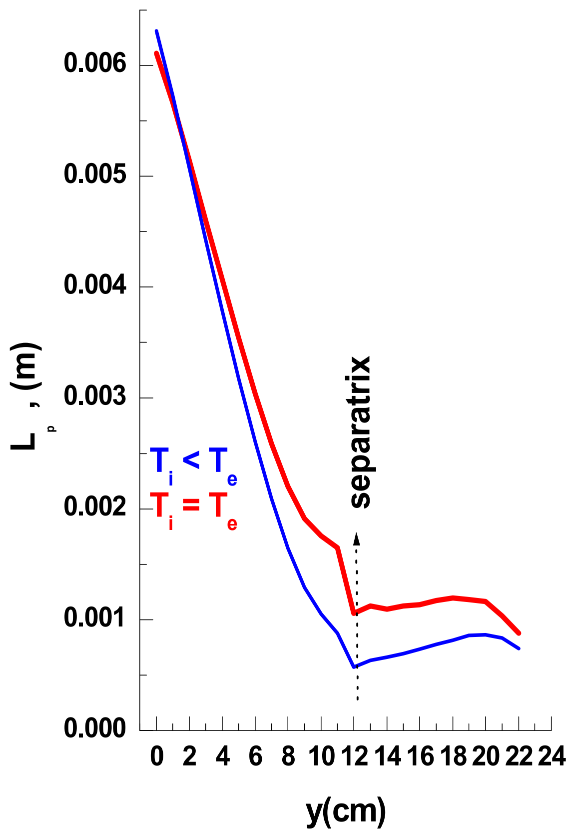


Figure 6. *Radial distribution of pressure characteristic scale length in the regimes with domination electron heating, ($T_i \leq T_e$) and couples ion-electron heating edge ($T_i = T_e$).*

The Fourth Result of Simulation show that, the radial distribution of plasma kinetic pressure 'P' and pressure characteristic scale length $L_P = |\partial lnP/h_y\partial y|^{-1}$ On the regimes dominated with electron heating ($T_i \leq T_e$) and equal electron-ion heating ($T_i = T_e$) are shown in figures 5-6. For the fully developed 'ETB' the central value of kinetic pressure and pressure characteristic scale length were (2.4, 0.8) *kpa*, and (0.0063 0.0061) *m*. The flex point of the pressure profiles as the barrier evolved was at y=12. In figure 6 the 'ETB' was initially apparent at the point ' y = 0', were exceeded 0.006 m. This result could be argued that, the pressure characteristic scale length 'L_P' is relevant for the formation of 'ETB'

The Fifth Result of Simulation the comparison of pressure characteristic scale length 'L_P' and stability parameter η_e ($\eta_e = L_T / L_n$ where L_T, L_n are normalized characteristic scale lengths of temperature and density are given by [9-11]) shows change in response to regimes with domination of electron heating ($T_i \leq T_e$) as seen in figures 5-6. This provides additional evidence for strong edge pressure profiles 'ETB' formation and there appears to be significant η_e constraint on those profiles. The formation of 'ETB' on the regimes of electron heating ($T_i \leq T_e$), the relative T_e and n_e profiles, shapes is constrained by $\eta_e|_{Ti < Te}$ =0.0063, namely the normalized characteristic length of electron temperature L_T have 0.0063 the value normalized characteristic length of density profile. The maximum pressure characteristic length appears to be limited by stability. Due to the coupling of characteristic length of electron density via the $\eta_e|_{Ti \leq Te}$ =0.0063 and $\eta_e|_{Ti = Te}$ =0.0061, the profile inside 'ETB' can be specified by a limit on the pressure characteristic scale length.

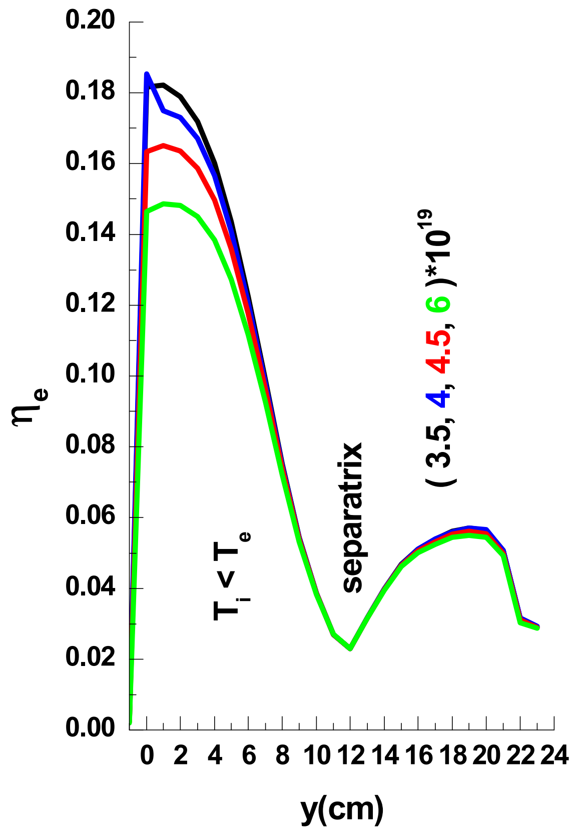


Figure 7. *Radial distribution of stability parameter in the region with domination electron heating ($T_i \leq T_e$).*

The Sixth Result of Simulation provides that, the radial profiles of stability parameter at different lines density as shown in figure 7. In the different plasma line density, the stability parameter η_e is, significantly, effected, although location 'ETB' foot does not move. Also figure 7 shows that lowing the line density result in an elevated the stability parameter η_e and effectively shifting of plasma density outboard. Due to the coupling of T_e and n_e characteristic scale lengths via the $\eta_e|_{Ti \leq Te}$ =0.0063 criterium, the edge profile inside and outside 'ETB' foot can be specified limit on the pressure gradient.

3. Conclusion

The *B2SOLPS5.0 2D multifluid transport code* has been used to model a small size divertor tokamak 'ETB'-mode discharge, with a focus on regimes with domination electron heating (i.e. $T_i \leq T_e$). Modeling of small size divertor tokamak on this regime leads to the following results:

(1). In small size divetor tokamak on regimes with domination electron heating, ($T_i \leq T_e$) have a strong effect on plasma density.

(2). A regime with domination electron heating, ($T_i \leq T_e$) have a strong influence on ion temperatures edge transport barrier, (IETB), which slowly move outward in the radial direction in the this regime.

(3). The depth of the radial electric field well in regime with dominant by electron heating is greater than the depth of the radial electric field in the regime dominated by coupled electron and ion heating. Within this framework, deeper 'E_r' wells provide stronger radial field shear, which increased capacity for turbulence suppression, leading to improved plasma confinement. Also the depth of the radial electric field is a function of electron temperature.

(4). The comparison of pressure characteristic scale length 'L_P' and stability parameter 'η_e' shows very little change in response to regime with electron heating, ($T_i \leq T_e$). This provides additional evidence for strong edge pressure profiles in 'ETB' and there appears to be significant 'η_e' constraint. Due to the coupling of characteristic lengths of electron temperature and plasma density via '$\eta_e = 0.006|_{Ti \leq Te}$, the profile inside 'ETB' can be specified by the limit on 'L_P'

(5). Lowing the plasma line density results in an elevated the stability parameter 'η_e' and effectively shifting of plasma density outboard.

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