THE INFLUENCE OF E×B DRIFT COMBINED WITH DIVERTOR DOME ON PLASMA DETACHMENT IN CFETR BY USING SOLPS-ITER

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The divertor dome can alter the closure of the in a tokamak, thereby affecting impurity shielding, particle exhaust, and divertor detachment[1–6]. The position of the dome in private flux region must be optimized in such a way: it is sufficiently 'open' to improve particle exhaust while also being adequately 'closed' to improve impurity shielding[7]. Additionally, the E×B drift can influence particle exhaust and divertor recycling[8]. However, in large-scale devices, the mechanisms of the dome effect on divertor plasma with impurity seeding under drift conditions remain unclear. In this work, the SOLPS-ITER code package is used to investigate the impact of domes on divertor detachment with Ne seeding considering E×B drift. Simulations are conducted for three different dome configurations—reference, small, and no dome—comparing cases with and without E×B drift. The D^+ density (n_{D+}) at core-edge-interface (CEI) is fixed $5\times10^{19}/m^3$ and input power is set to 200MW. The various configurations are illustrated in Figure 1. Ne seeding rate ranges from 0 to $5\times10^{20}/s$. It has been found that the dome significantly impacts divertor detachment, particularly in the far SOL region of the divertor. In absence of a dome, neutral particles diffuse more easily into the SOL, which reduces electron temperature (T_e) in the far SOL, see Figure 2. This observation contradicts the common understanding that increased divertor closure contributes to detachment. The reason for this discrepancy lies in the fact that, for large devices, the absence of a dome facilitates neutral particle diffusion into the far SOL, increases the plasma wetted area, density decay length and radiation, thereby promoting detachment. In traditional designs, the benefits of divertor closure arise from the limited spatial scales of medium and small devices. In contrast, CFETR's dome-free configuration achieves more efficient detachment by harnessing the natural physical processes (e.g., neutral particle diffusion and recombination) at an amplified scale. When considering the E×B drift in forward B_t (where $B\times\nabla B$ point to X-point), the drift has a more pronounced effect on plasma in ID than in OD with a dome. In cases without a dome, achieving plasma detachment in the divertor regions is more feasible in reversed B_t, as illustrated in Figure 3. Regardless of increased impurity seeding rates or the influence of drift effects, the dome suppresses neutral particle diffusion into the outer divertor SOL, thereby mitigating the impact of drift and impurities on plasma in the OD. Furthermore, the radial drift consistently plays a critical role in divertor plasma behavior. However, when impurity seeding rates are extremely high, configurations without a dome permit a greater influx of impurities into the core plasma, increasing the risk of discharge disruption. In the future, the dome design should balance between being sufficiently open to enhance far SOL radiation and remaining adequately closed to prevent impurity particles from contaminating the core. A comprehensive understanding of how domes influence plasma detachment and impurity shielding under drift effects in large-scale tokamak devices is essential for enabling long-plus steady-state operation of future fusion reactors.

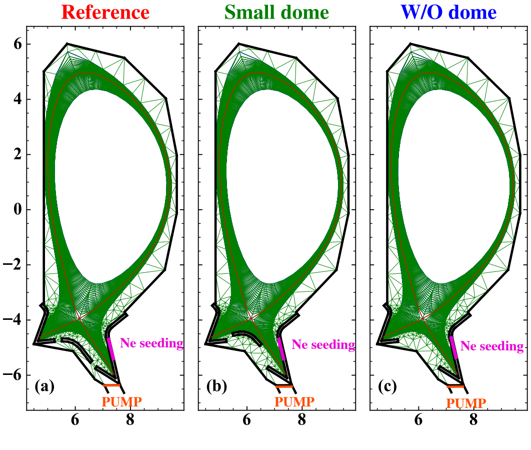

Figure 1 Sketch of computational grids with reference dome, small dome and without dome.

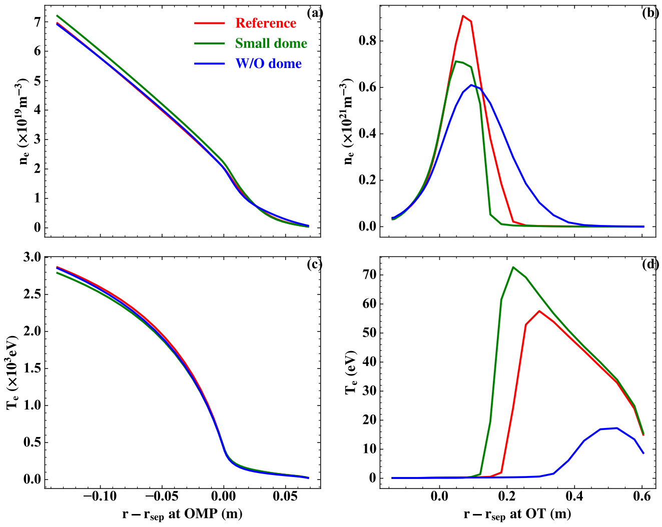

Figure 2 Profiles of (a, b) n_e and T_e (c, d) along (a, c) OMP or (b, d) OT with various dome configurations. The puffing Ne rate is 1.0×10^{20}/s.

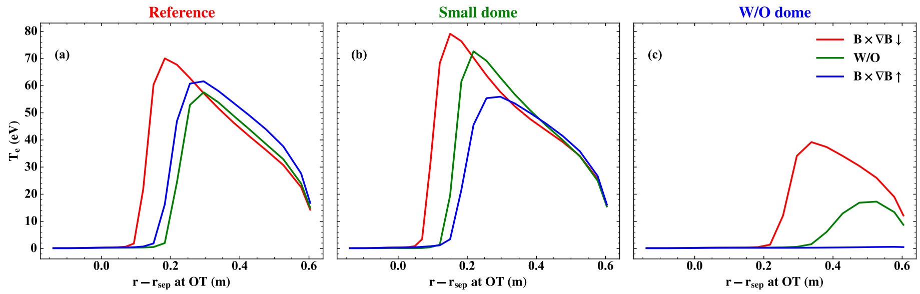

Figure 3 Profiles of T_e along the OT in (a) reference, (b) small, and (c) absence dome configurations, with E×B drift in forward/reversed B_t or without drift. The puffing Ne rate is 1.0×10^{20}/s.

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REFERENCES

[1] Yang H et al 2022 *Nuclear Materials and Energy* **33** 101302
[2] Wang H Q et al 2018 *Nucl. Fusion* **58** 096014
[3] Day C et al 2016 *IEEE Trans. Plasma Sci.* **44** 1636–41
[4] Sang C F et al 2020 *Nucl. Fusion* **60** 056011
[5] Sang C et al 2021 *Nucl. Fusion* **61** 016022
[6] Zhao X et al 2024 *Nucl. Fusion* **64** 086058
[7] Loarte A 2001 *Plasma Phys. Control. Fusion* **43** R183–224
[8] Zhao X et al 2022 *Nuclear Materials and Energy* **33** 101317