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

Xuele Zhao[1], Yilin Wang[1], Chaofeng Sang[1,*], Xiaoju Liu[2], Rui Ding[2], Chen Zhang[1] and Dezhen Wang[1]
[1]School of Physics, Dalian University of Technology, Dalian 116024, China
[2]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China
*Email: sang@dlut.edu.cn

Abstract

The dome can modify the closure in a tokamak, thereby influencing impurity shielding, particle exhaust, and divertor detachment [1–6]. The strong coupling between the divertor configuration and drifts can significantly impact plasma detachment in the divertor region. However, in large-scale devices, the mechanisms by which the dome affects divertor plasma with impurity seeding under drift conditions remain unclear. In this study, the SOLPS-ITER code package is used to investigate the impact of domes on divertor detachment with Ne seeding, considering E×B drift. It was found that the dome significantly influences divertor detachment, particularly in the far SOL region of the divertor. In the absence of a dome, neutral particles diffuse more readily into the SOL, which reduces T_e in the far SOL. This observation contradicts the common understanding that increased divertor closure promotes detachment. The discrepancy arises because, in large devices, the absence of a dome facilitates neutral particle diffusion into the far SOL, increasing the plasma wetted area, density decay length, and radiation, thereby contributing to detachment. When considering the E×B drift in forward B_t, the drift has a more pronounced effect on plasma in ID than in OD with a dome. In configurations without a dome, achieving plasma detachment in the divertor regions is more feasible in reversed B_t. 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, radial drift consistently plays a critical role in divertor plasma behavior. However, at extremely high impurity seeding rates, configurations without a dome allow a greater influx of impurities into the core plasma, increasing the risk of discharge disruption. 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-pulse steady-state operation of future fusion reactors.

Simulation setup

Main parameters:

- ✓ First wall: W
- ✓ D+Ne (including all charge states)
- ✓ D^+ at CEI: 5×10^{19} m^{-3}
- ✓ Puffing Ne rate: $0\sim5\times10^{20}$/s
- ✓ Input power: 200MW
- ✓ Including E×B drift
- ✓ Anomalous transport coefficient: 0.3 m^2/s
- ✓ Recycling coefficient: 0.985

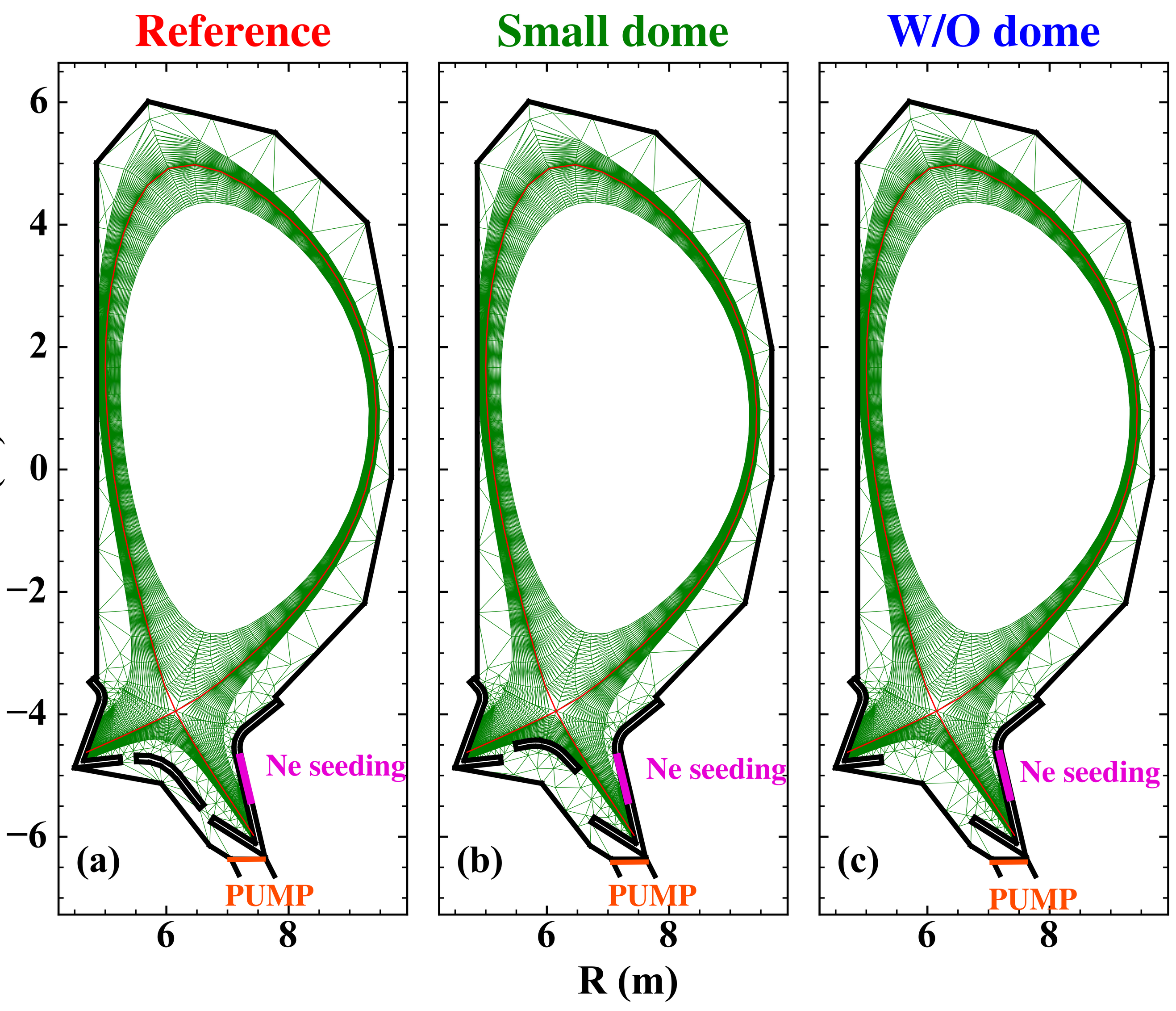

Figure 1 Sketch of computational grid with different dome geometries in CFETR

Simulation results

1 Effect of dome on plasma and neutral particles in divertor region

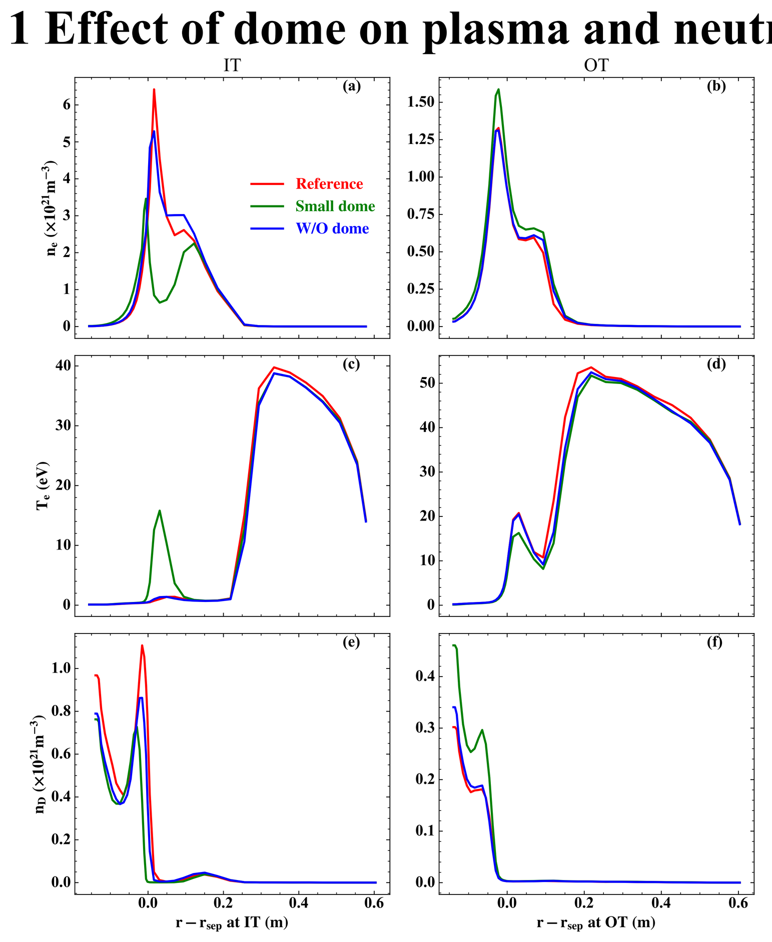

Figure 2 Comparison of plasma profiles at targets without Ne injection

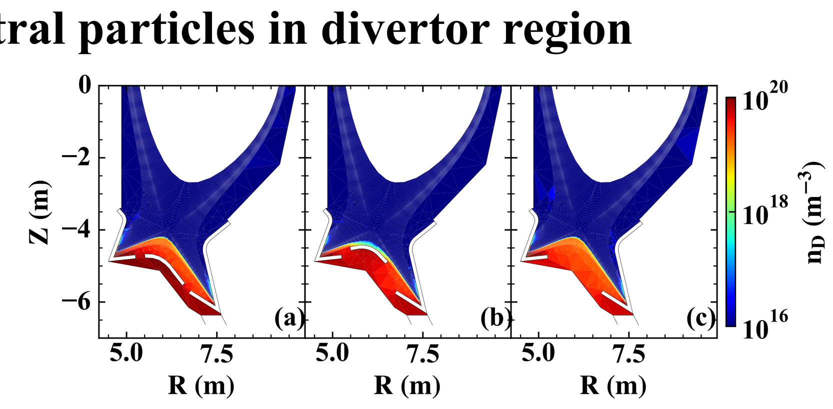

Figure 3 Comparison of neutral density for D without Ne injection

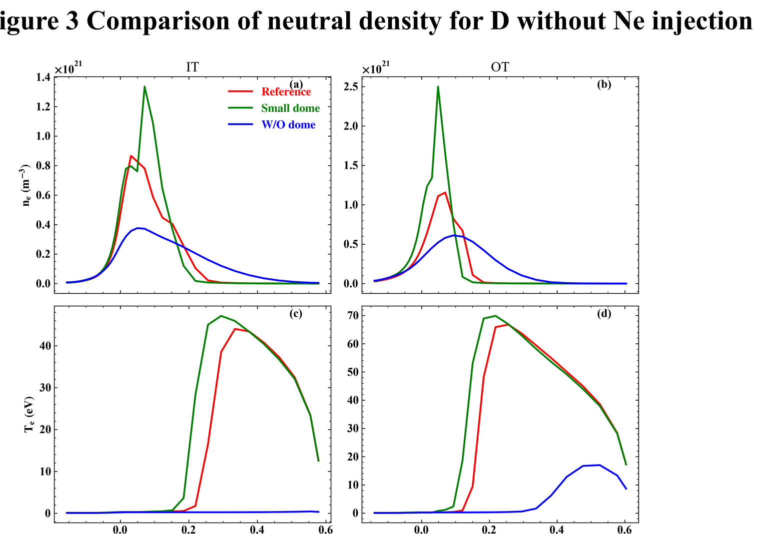

Figure 4 Comparison of n_e and T_e at target with Ne injection

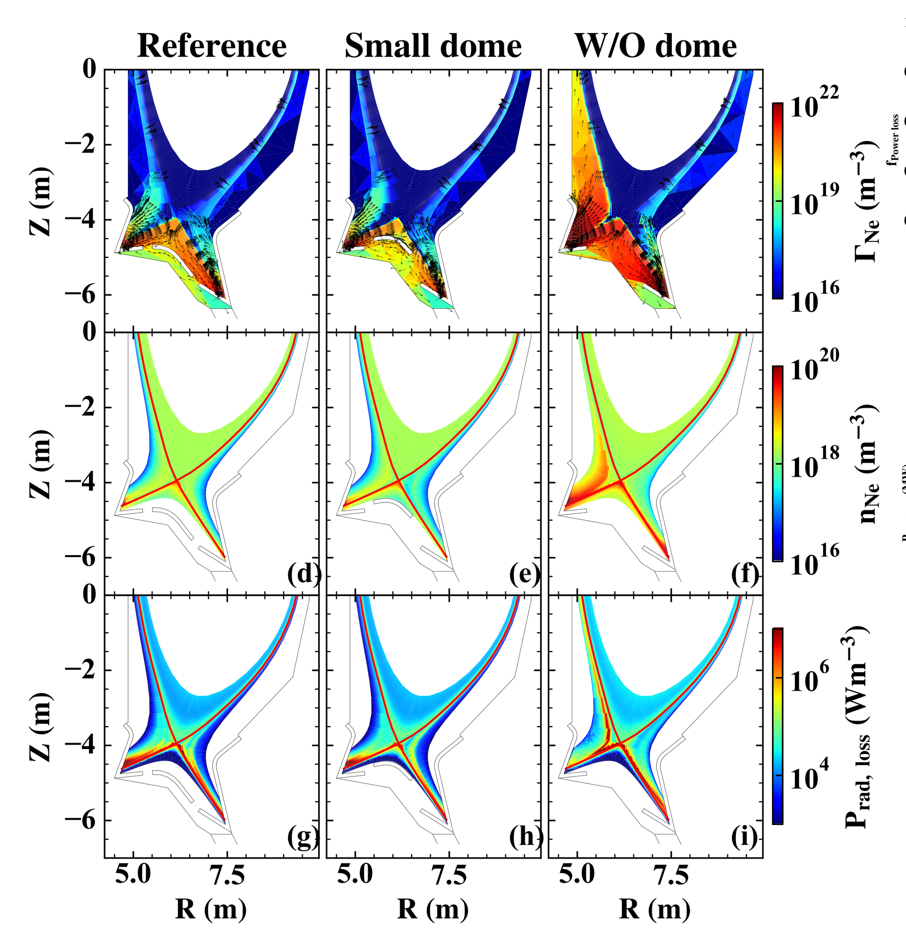

Figure 5 Comparison of Ne density and radiation distribution with Ne injection

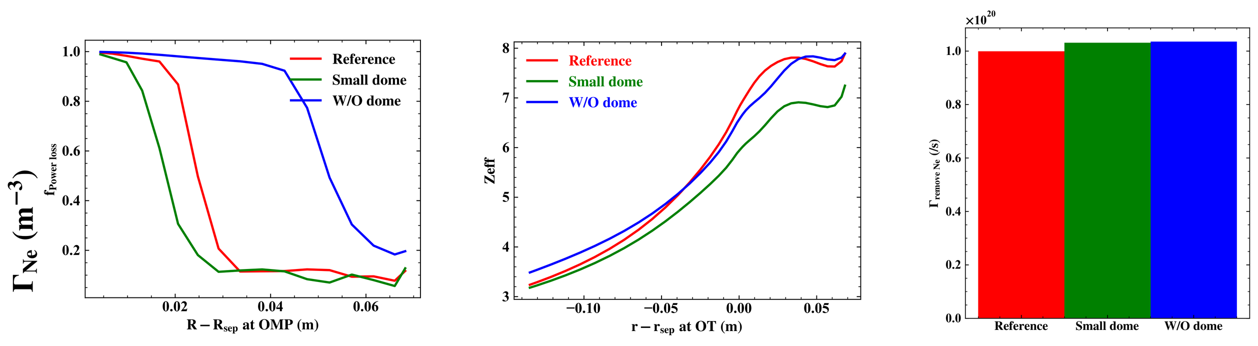

Figure 6 Comparison of radiation loss factor, Z_{eff}, and particle exhaust for Ne

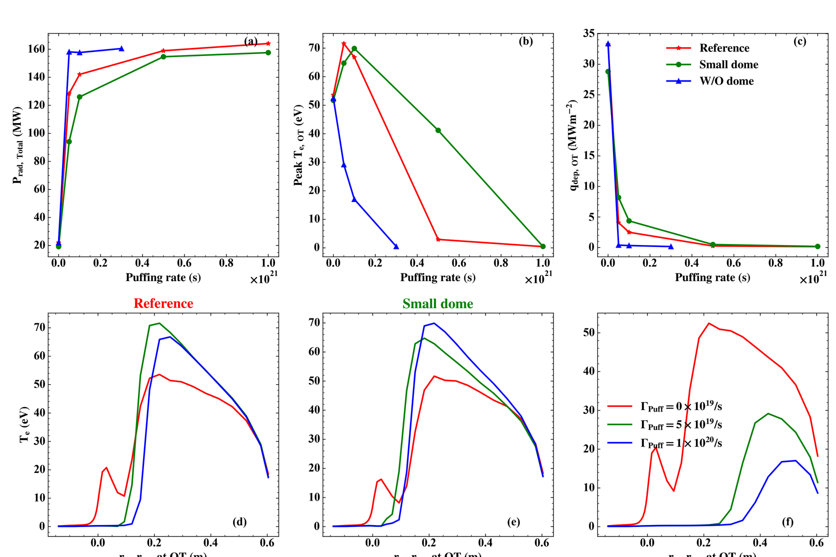

Figure 7 Comparison of total radiation and T_e with different puffing rates

- ❑ Without Ne injection, small dome is disadvantageous for detachment.
- ❑ Dome have a significant compressive effect on neutral particles located beneath them.
- ❑ With Ne injection, the absence of a dome is beneficial for plasma detachment.

2 Effect of E×B drift on plasma in divertor regions with different dome geometries

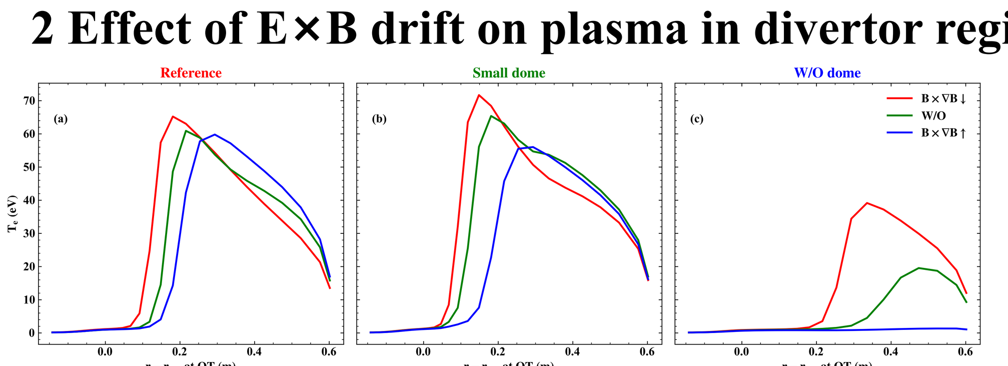

Figure 8 Comparisons of T_e at OT in different B_t direction under different dome configurations

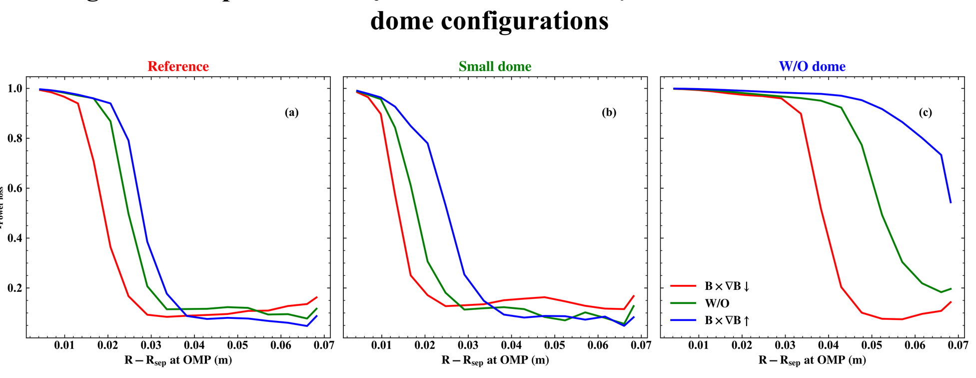

Figure 9 Comparisons of energy loss factor in OD under different dome configurations

- ❑ Radial E×B drift significantly affects T_e
- ❑ In OD: E×B drift decreases power loss factor in near SOL in forward B_t, while it increases the power loss factor in the near SOL in reversed B_t
- ❑ The $f_{power\ loss}$ of the W/O dome is greater than that of the dome. The W/O dome is beneficial for enhancing radiation in the far SOL.

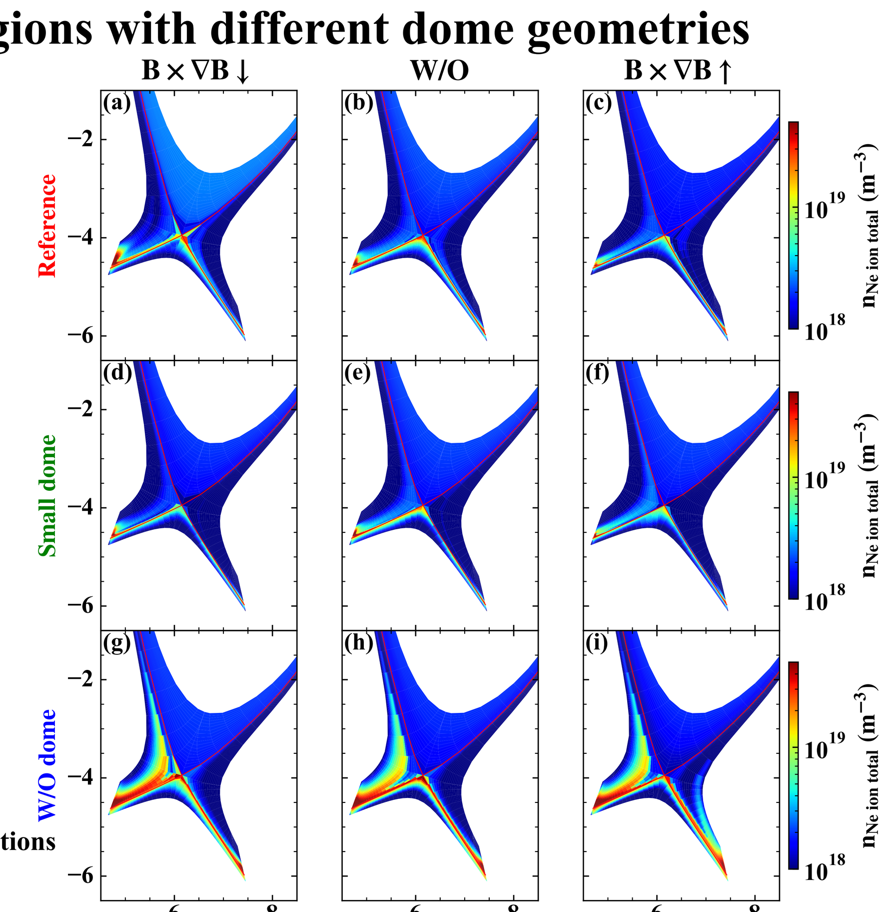

Figure 10 Comparisons of Ne ion distribution under different dome configurations

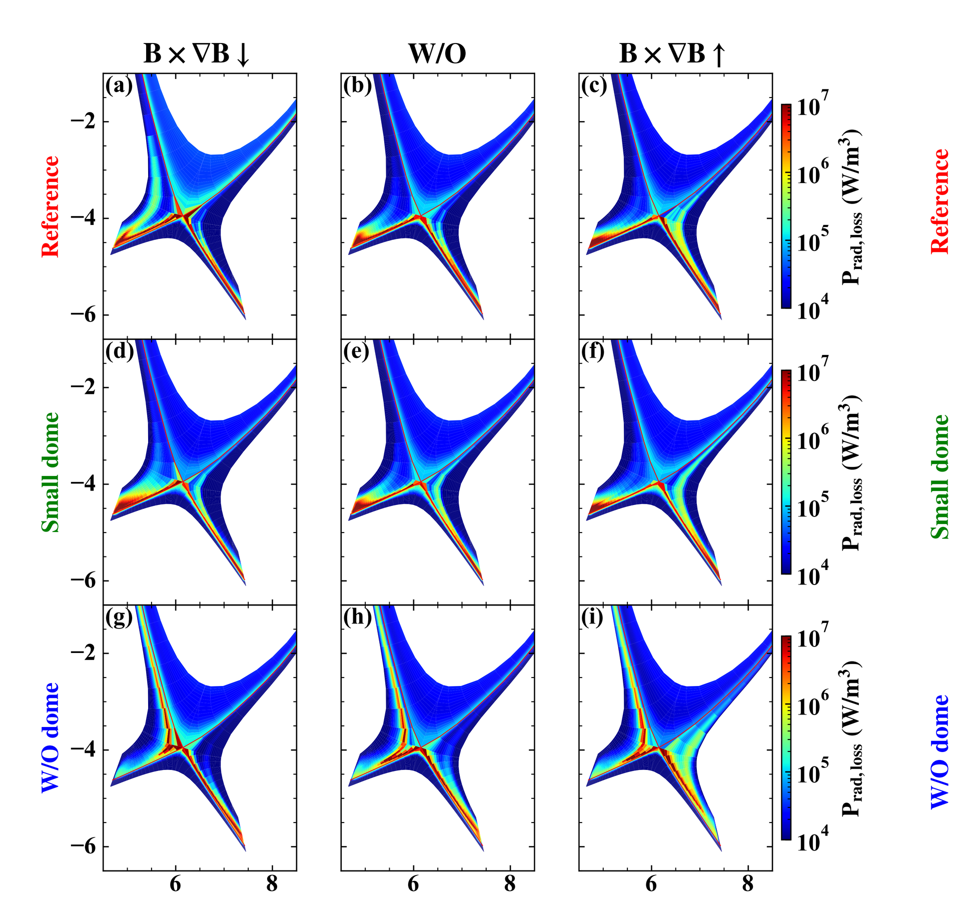

Figure 11 Comparisons of radiation distribution under different dome configurations

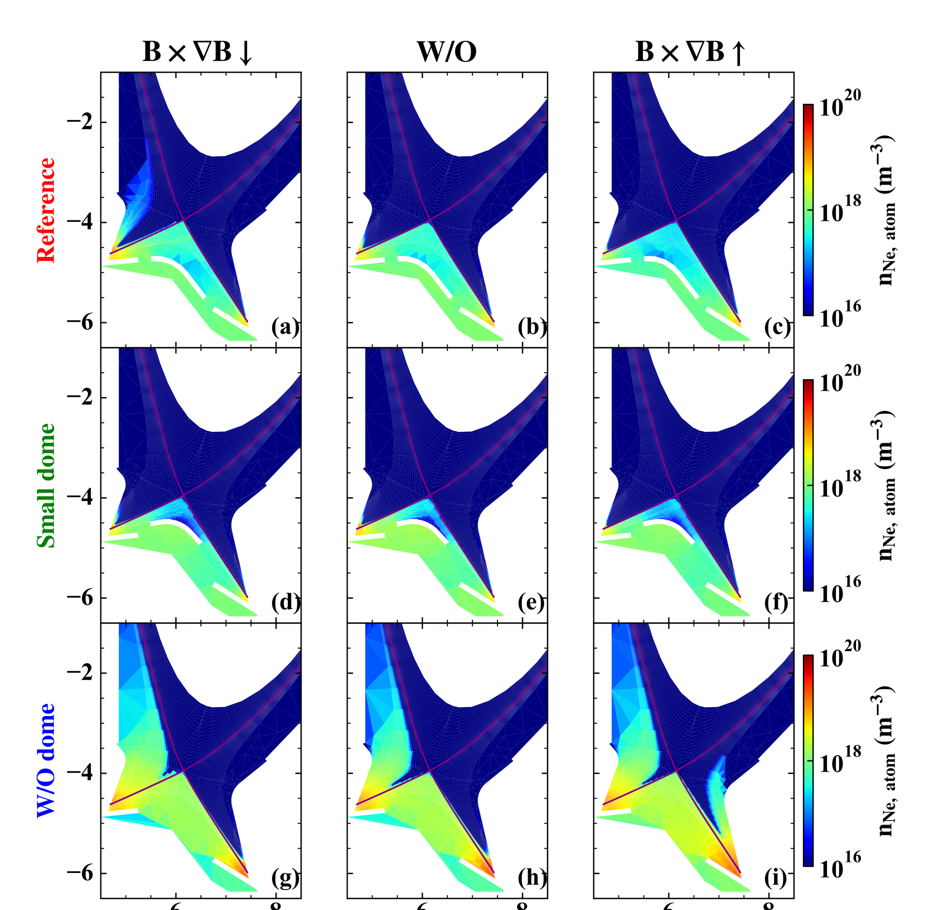

Figure 12 Comparisons of Ne atom distribution under different dome configurations

- ❑ Dome can affect the drift effect on the distribution of Ne ions, thereby influencing the radiation distribution.
- ❑ Drift in reversed B_t can increase Ne ion density in the OD W/O dome and enhance radiation in the OD, thus promoting the achievement of detachment.
- ❑ For reference, drift in the forward B_t can enhance particle recycling in ID, thereby facilitating the entry of neutral particles and impurity ions into the inner divertor SOL; in the absence of a dome, drift in reversed B_t enhances particle recycling in OD, thereby promoting the entry of impurities into the outer divertor SOL.

Conclusion

- ◆ Dome significantly affects plasma detachment, especially in the far SOL.
- ◆ In the dome-free configuration, neutral particles diffuse more easily into the SOL, which more effectively reduces the T_e in the far SOL, resulting in a larger energy loss factor there. Consequently, both the inner and outer divertors in the reversed B_t configuration without a dome achieve detachment more readily.
- ◆ Whether by increasing the impurity injection rate or accounting for the drift effect, the dome can suppress the diffusion of neutral particles into the outer divertor SOL, thereby mitigating the impact of drifts or impurities on the plasma in the outer divertor region.
- ◆ Radial drift consistently plays a significant role in influencing the divertor plasma.
- ◆ When the impurity injection rate is extremely high, a greater number of impurities enter the core in the W/O dome configuration, which tends to cause discharge disruption.

Reference

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