In-out asymmetry of the divertor particle flux and the detachment phenomenon on HL-2A tokamak

N. Wu[1], K. Y. Yi[1], W. C. Wang[1], Z. H. Huang[1], L.W. Yan[1], J. Cheng[2], H. L. Du[1], Z. B. Shi[1], W. L. Zhong[1], M. Xu[1]

[1]Southwestern Institute of Physics, [2]Institute of Fusion Science, School of Physical Science and Technology, Southwest Jiaotong University

e-mail (speaker): wuna@swip.ac.cn

It is a great challenge to maintain tolerable heat and particle flux on the divertor target in the future fusion reactor. The divertor detachment operation is an effective way to mitigate the divertor heat flux. The divertor particle flux in tokamak[1-3] usually shows in-out asymmetry, which is related the detachment process closely[4], and this phenomenon may be attributed to different factors, such as the $E \times B$ drift, ballooning transport, connection length and so on[5]. The closeness of the divertor is favorable to reach the high neutral pressure and obtain the detachment in ITER[6]. Therefore, it is necessary to investigate the inner-outer asymmetry and the detachment physics of HL-2A, which has a very closed divertor structure.

The in-out asymmetry of the divertor particle flux and the detachment phenomenon have been investigated on HL-2A tokamak. In the favorable B_t case, the particle flux amplitude on the outer divertor is smaller than that on the inner divertor in low density discharge, and it shows a wider particle flux profile on the outer divertor than that on the inner divertor target, as shown in the first shadow region in the Fig.1 and Fig. 2(a). The in-out asymmetry is weakened with the density increasing, which can be seen in the second shadow window in Fig.1 and Fig.2(b). The detachment usually appears firstly on the inner divertor when the density is large enough. It is opposite in the unfavorable B_t case, i.e. the particle flux amplitude on the outer divertor is larger and shows a narrower profile than that on the inner divertor in the low density discharge. The detachment takes place on the inner divertor firstly as well with the density increasing. The preliminary analysis suggests that the in-out asymmetry of the divertor particle flux is mainly attributed to the $\boldsymbol{E} \times \boldsymbol{B}$ drift, which is depended on the plasma potential distribution and can be influenced by the plasma density, heating power and the divertor structure.

The detachment is easy to be obtained in the low power discharges, and the density threshold for the detachment increases with the heating power. Impurity seeding in the divertor is required in the detachment operation of H-mode discharge. The partial detachment accompanied by the edge localized mode (ELM) mitigation and the increase of core ion temperature is obtained via the nitrogen impurity seeding in the divertor vacuum chamber. There is no observable confinement deterioration during the partial detachment. The compatibility of the detachment and the high performance plasma may be attributed to the closed divertor structure, which restricts the impurity into the core plasmas and sustains the high neutral pressure of the divertor without contaminating the core plasmas. These results provide reference for the divertor design aiming to the detachment operation of future fusion reactor.

This work is supported by National Natural Science Foundation of China under Grant No. 11905052, and Sichuan Science Foundation under Grant 2022NSFSC1820

References

[1] Rognlien T. D. *et al* 2017 *Nucl. Mater. Energy* **12** 44-50
[2] Pitts R. A. *et al* 2005 *J. Nucl. Mater.* **337** 146-153
[3] Chankin A. V. *et al* 2015 *Plasma Phys. Control. Fusion* **57** 095002
[4] Jaervinen A. E. *et al* 2018 *Phys. Rev. Lett.* **121** 075001
[5] Boedo J. *et al* 2018 *Plasma Phys. Control. Fusion* **60** 044008
[6] Pitts R. A. *et al* 2019 *Nucl. Mater. Energy* **20** 100696

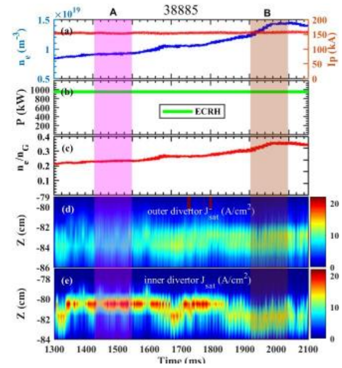

Figure 1 The inner-outer asymmetry evolution of the divertor J_{sat}: (a) the n_e and I_p; (b) the ECRH power; (c) the normalized density; the J_{sat} distribution on the outer (d) and inner (e) divertor.

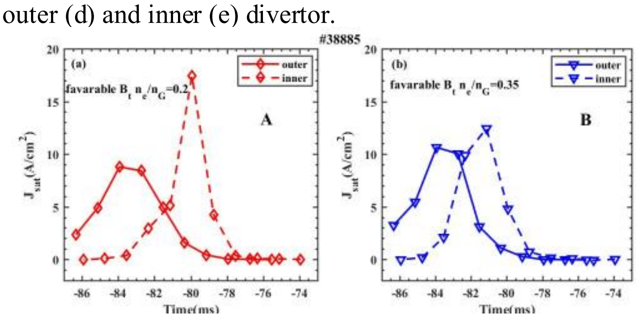

Figure 2 The divertor J_{sat} profiles in different normalized density.