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The mechanism research of double strike points of the divertor particle flux in HL-2A ECRH plasmas

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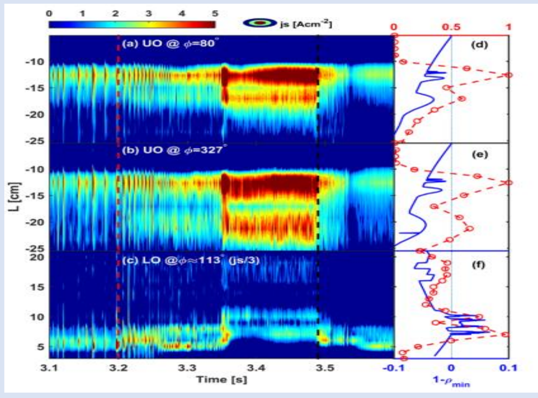
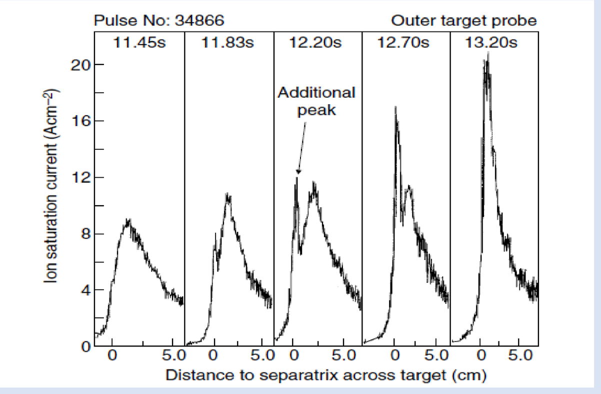
BACKGROUND

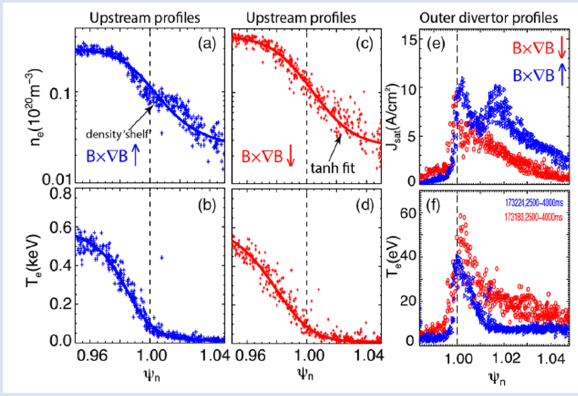
- $P_{aux} + P_{fusion} = P_{neutron} + P_{rad,main} + P_{sep}$
- The $P_{sep} = 100$ MW for the ITER;
- One method of the heat flux mitigation is to increase the wetted area on the divertor target.



[1] M Jia NF 2016(58) 055010



[4] A V Chankin PPCF 2001(43)299-304



[5] H Q Wang PRL 2020(124)195002

- The double strike point (DSP) induced by the stochastic field due to the RMP have been observed in many tokamaks [1-3];
- The DSP are observed on the outer divertor target in the **unfavorable B_t case** without the stochastic field on JET Mark I [4] and DIII-D [5];
- The DSP are observed on the outer divertor target during the ECRH plasma discharge in the **favorable B_t case** on HL-2A;

EXPERIMENTAL SETUP

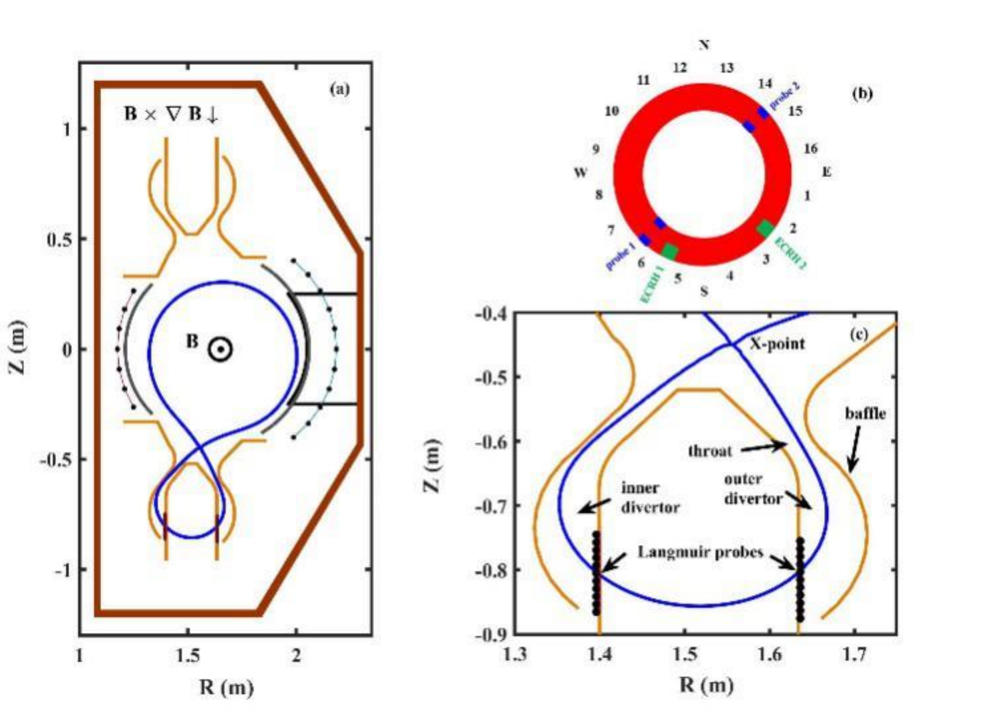


FIG. 1 The cross section of HL-2A tokamak

- $n_e = 0.8\sim1.2 \times 10^{19}\ m^{-3}$
- $I_p \approx 150$ kA
- $B_t = 1.2\sim1.4\ T$
- $\mathbf{B} \times \nabla\mathbf{B}$ pointing to the X point
- Measured region of the divertor probes:
  $Z = -0.745 \sim -0.865$ m
  $Z = -0.755 \sim -0.875$ m
- The temporal spatial resolution are 1kHz and 6 mm, respectively.

OUTCOME

◆ *The evolution of the DSP with the density increasing during the ECRH (the secondary peak appears in the SOL)*

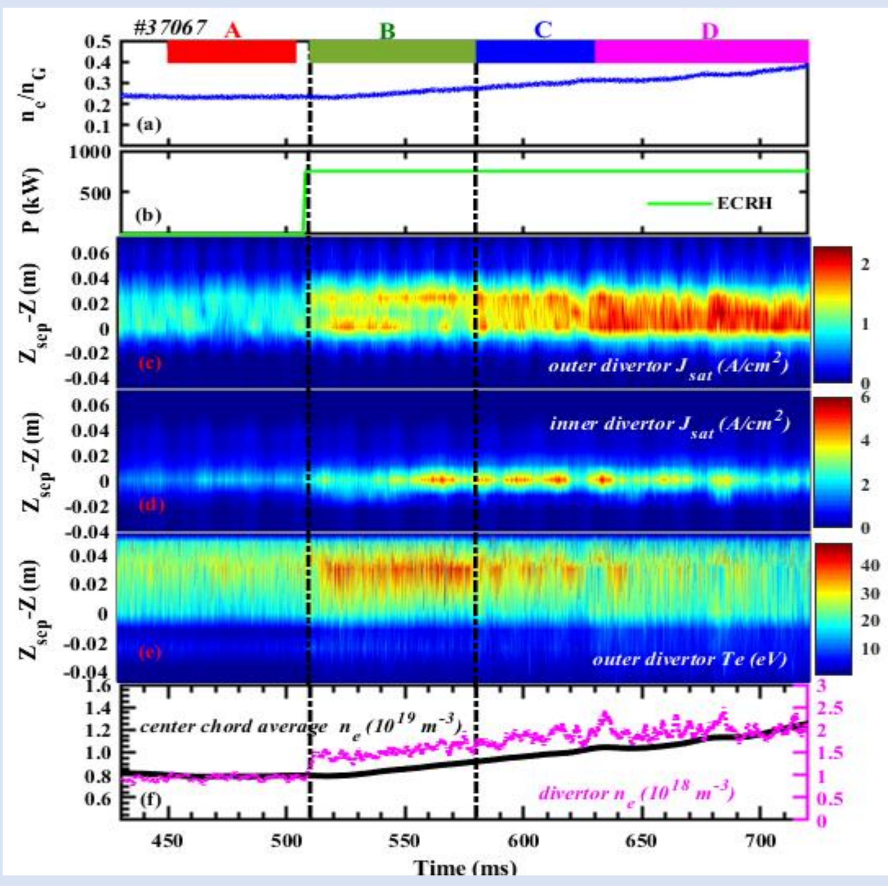


FIG. 2 The typical experiment observations of the DSP of the particle flux with density increase during the ECRH plasmas

- **DSP are observed on the outer divertor target not on the inner divertor target;**
- **It appears when the ECRH is turn on and disappears with the increase of the density;**
- **This results should not be attributed to the error field:**
  - **The density is increasing when the DSP appear, because the penetrate threshold is $(b_r/B_T)_{crit} \sim n_e B_T^{-1.8} R_0^{0.25}$**
  - **No DSP is observed from the T_e.**
- **Both the T_e gradient, E_r and the V_θ are large when the DSP appears;**
- **There is a large outer shift of the temperature peak due to the long leg of the divertor on HL-2A, which cause the positive E_r and the reversed poloidal drift flow.**

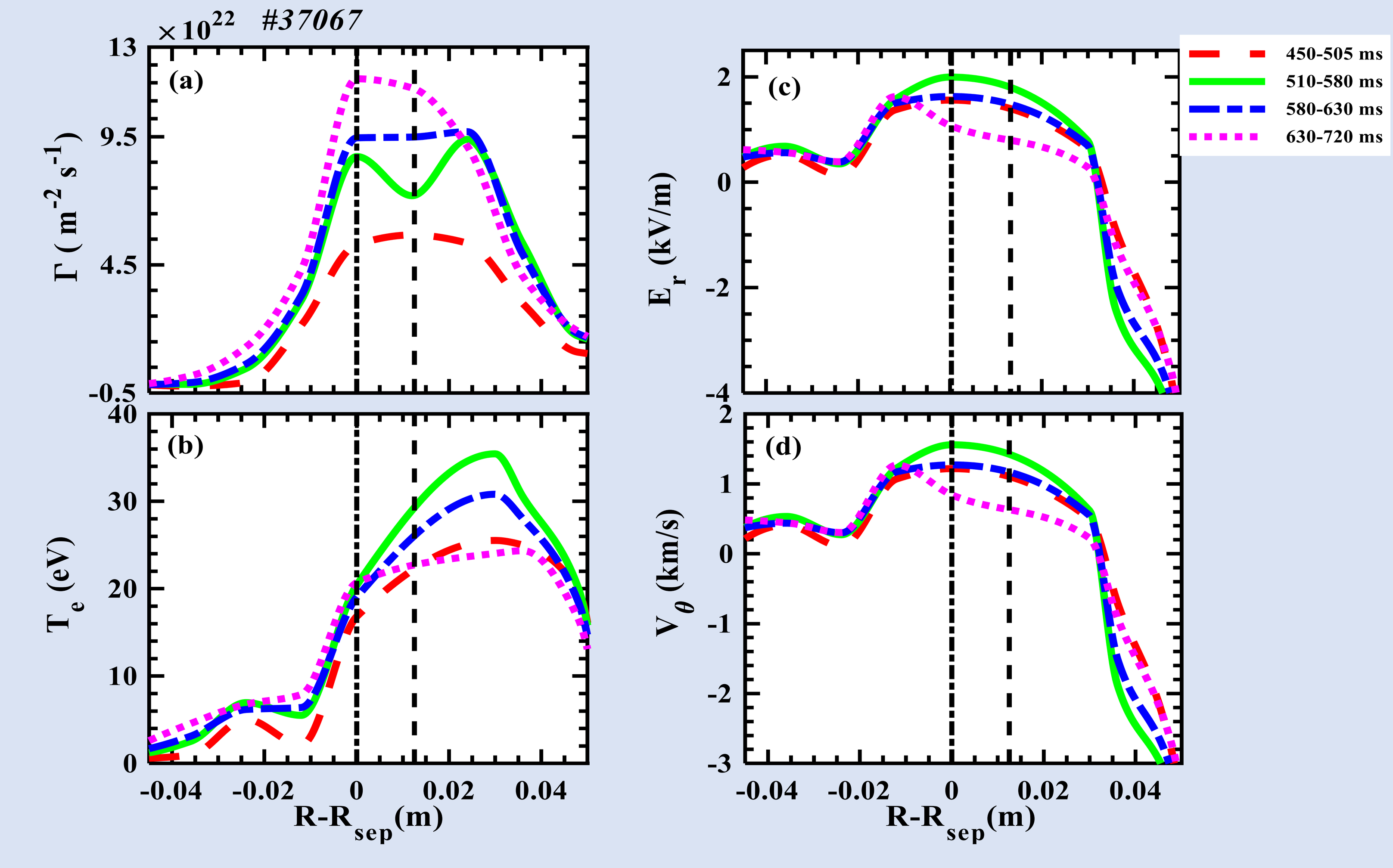


FIG. 3 The profiles of (a) saturation ion current density, (b) electron temperature, (c) the radial electric field, (d) poloidal $E \times B$ velocity on the outer divertor target.

PHYSICAL ANALYSIS

◆ *The estimation of the poloidal drift flow*

According to the Bohm-Chodura criterion [6]:

$$\sin\theta V_{\parallel 0} + \underbrace{\frac{\cos\theta E_r}{|B|}}_{(1)} - \frac{\cos\theta \nabla P}{en|B|} = \underbrace{\sin\theta C_s}_{(2)}$$

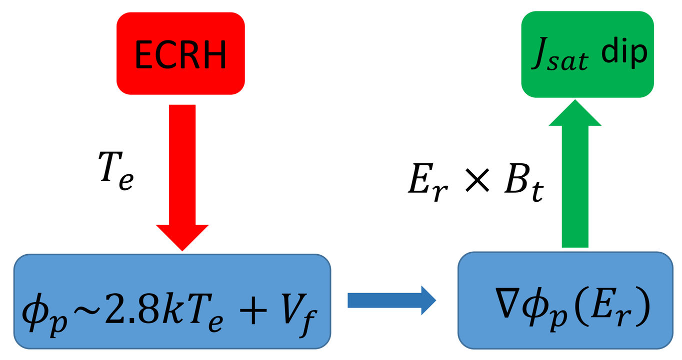
(1) $\frac{\cos\theta E_r}{B_t} = \frac{1.841kV/m}{1.275T} = 1.44km/s$

(2) $\sin\theta C_s = B_\theta \times C_s/B \sim 5\ km/s$

Assumming $T_e \approx T_i$, the ion-acoustic velocity is : $C_s = \sqrt{(T_e + \gamma T_i)/m_i} \sim 50km/s$

The poloidal electric drift flow is the same order as the poloidal projection of the ion-acoustic velocity, therefore the reverse poloidal flow is large enough to cause the dip of the J_{sat}.

◆ *The physical process*



The DSP are located at the high ECRH power and low density region, which support the physical mechanism.

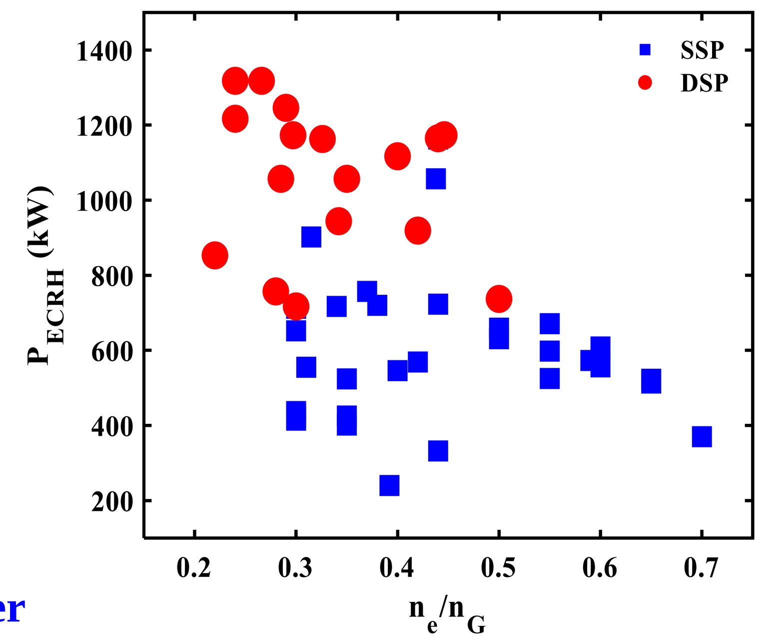


FIG. 4 The dependence of the DSP on the normalized electron density and the ECRH power

DISCUSSION

◆ *The evolution of the DSP with the density decrease during the ECRH (the secondary peak appears in the PFR)*

The pump out of the density induced by the ECRH may cause a change of the parallel electron pressure and poloidal electric field, thus a different radial drift flow from the shot 36076 are generated.

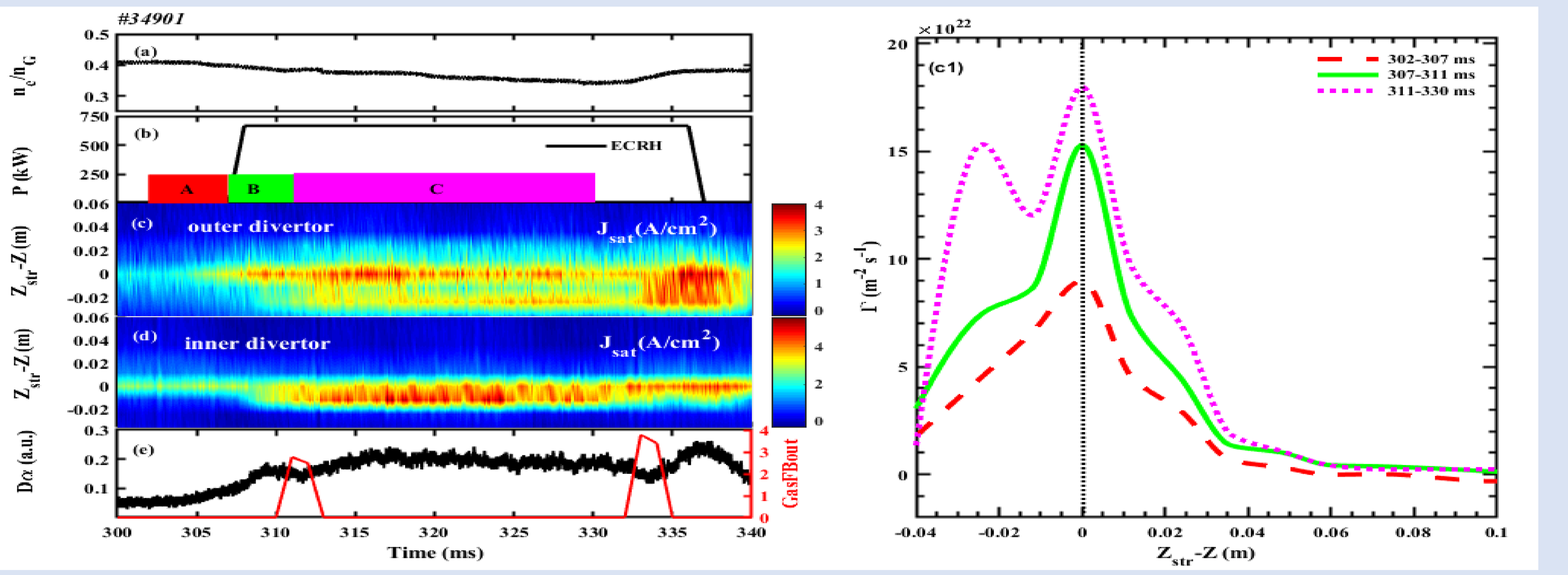


FIG. 5 The typical experiment observations of the DSP of the particle flux with density decrease during the ECRH plasmas

CONCLUSION

- **DSP of the particle flux have been observed on the outer divertor target during the HL-2A ECRH plasma discharge in the favorable B_t using the Langmuir probe arrays;**
- **The poloidal E × B drift velocity may play an important role in the formation of the dip of the particle flux;**
- **The T_e peak is far away from the peak of the particle flux in the SOL due to the large radiation of the long leg of the divertor, resulting in a reversed poloidal drift flow on the outer divertor target;**
- **The statistical results show that the DSP phenomenon occurs in the high ECRH power and the low density region;**
- **The paper highlights the important role of the poloidal E × B drift and the long leg divertor in the control of the particle flux, which provides some reference for the heat flux mitigation in the future fusion devices.**

ACKNOWLEDGEMENTS

This work is supported by National Natural Science Foundation of China under Grant Nos. 11905052, 11875017, 11875020, 11820101004, and National Key R&D Program of China under Grant Nos. 2019YFE03030002, 2019YFE03040002, 2019YFE03090400, 2017YFE0301203, 2017YFE0301106. The authors would like to appreciate the support of Sichuan outstanding youth Science Foundation under Grant No.2020JDJQ0019

REFERENCES

[1] Jia M. *et al.* Plasma Physics and Controlled Fusion 58, (2016).
[2] Thornton A. J. *et al.* Nuclear Fusion 54, (2014) 064011.
[7] Kim K. *et al.* Physics of Plasmas 24, (2017) 052506.
[4] Chankin A. V. *et al.* Plasma Phys. Control. Fusion 43, (2001) 299-304
[5] Wang H. Q. *et al.* Physical Review Letters 124, (2020).
[6] Stangeby P. C. *et al.* Physics of Plasmas 2, (1995) 707-715.