

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

N. Wu¹, J. Cheng², L.W. Yan¹, Z.H. Huang¹, H.L. Du¹, W.C. Wang¹, X.G. Miao¹, J.M. Gao¹, J.Q. Xu¹, Z.B. Shi¹, Y. Liu¹, Q.W. Yang¹, J.Q. Dong¹, M. Xu¹

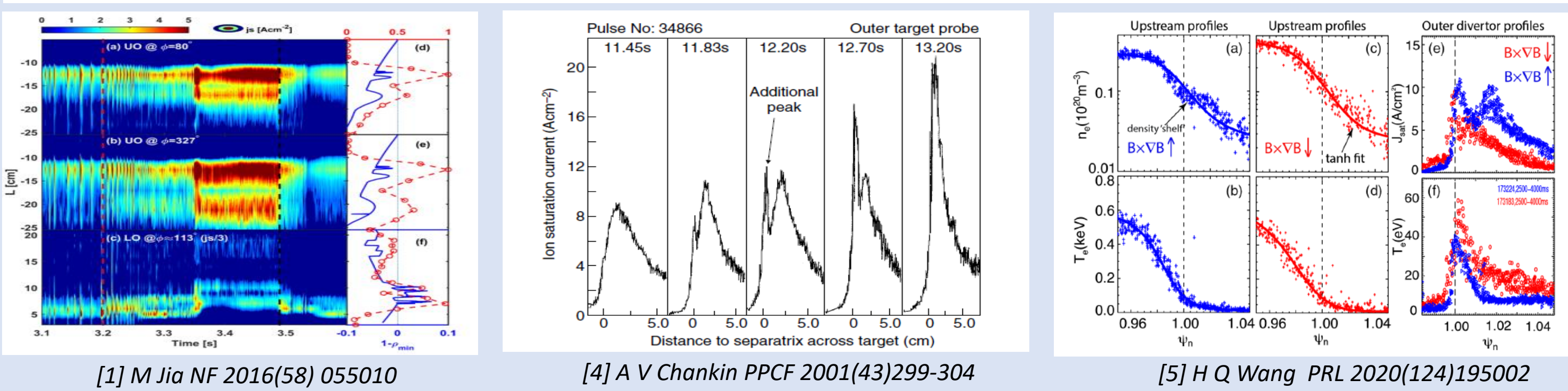
¹ Southwestern Institute of Physics, Chengdu, 610041, People's Republic of China

² Institute of Fusion Science, School of Physical Science and Technology, Southwest Jiaotong University, Chengdu, 610031, People's Republic of China

wuna@swip.ac.cn

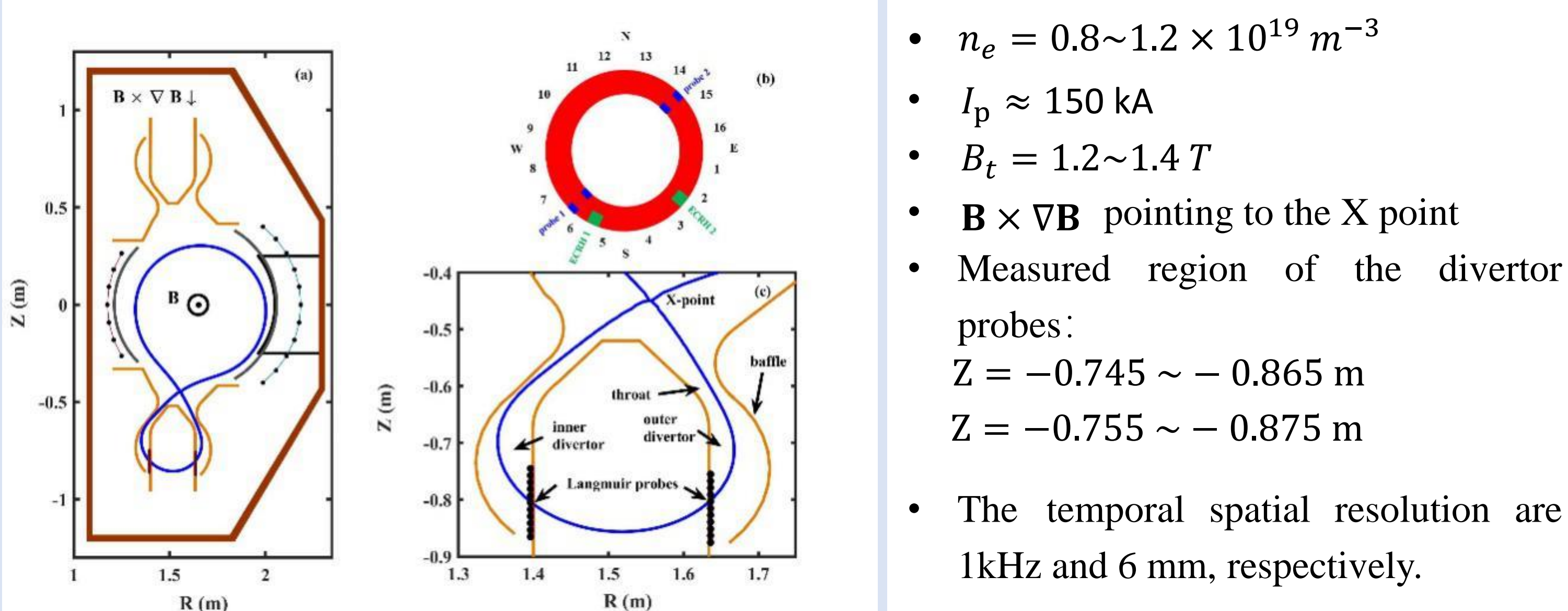
BACKGROUND

- $P_{aux} + P_{fusion} = P_{neutron} + P_{rad,main} + P_{sep}$
- 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.



- 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



- $n_e = 0.8 \sim 1.2 \times 10^{19} \text{ m}^{-3}$
- $I_p \approx 150$ kA
- $B_t = 1.2 \sim 1.4$ 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.

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

OUTCOME

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

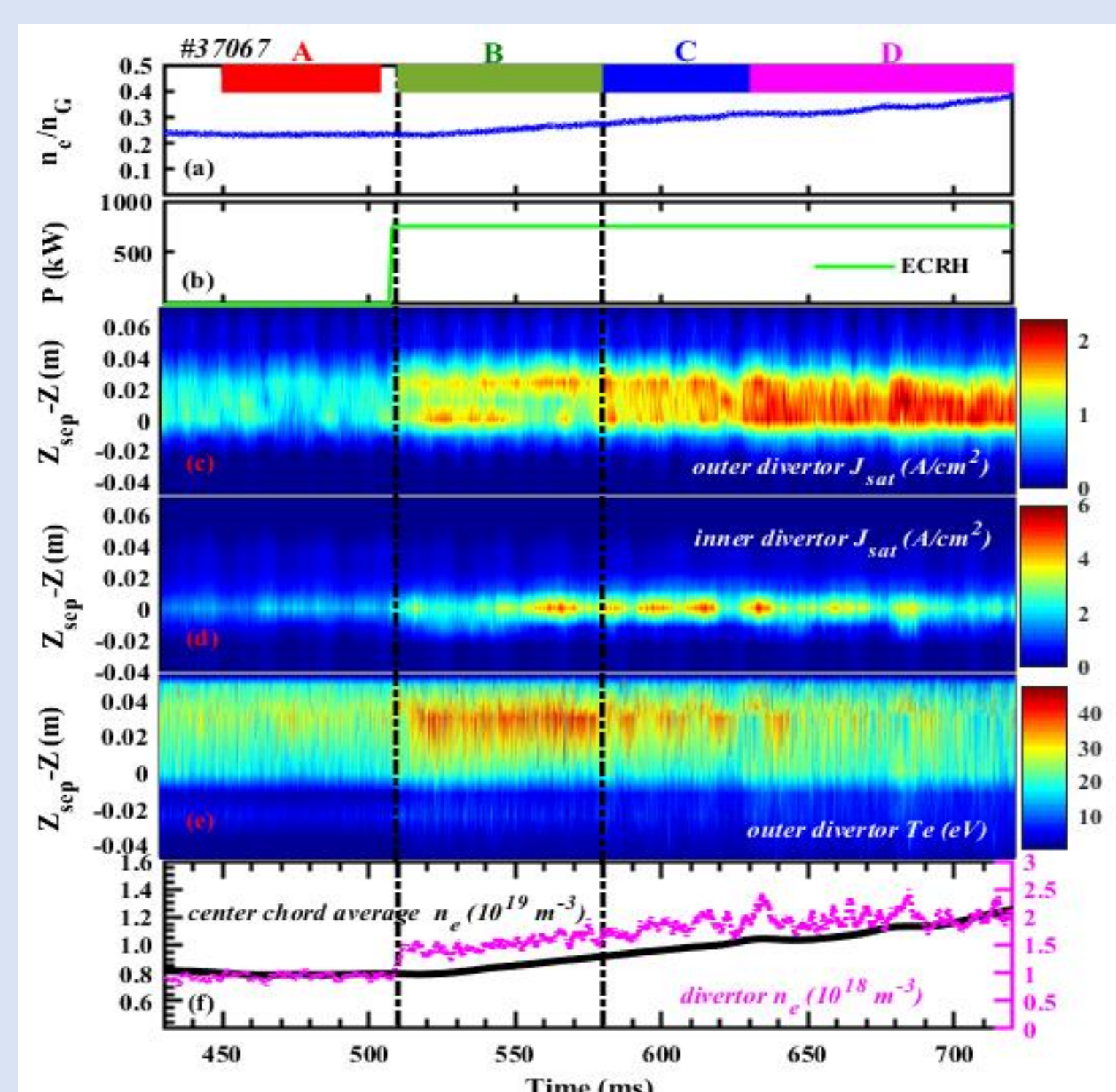


FIG. 2 The typical experiment observations of the DSP of the particle flux with density increase during the ECRH plasmas

- 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.

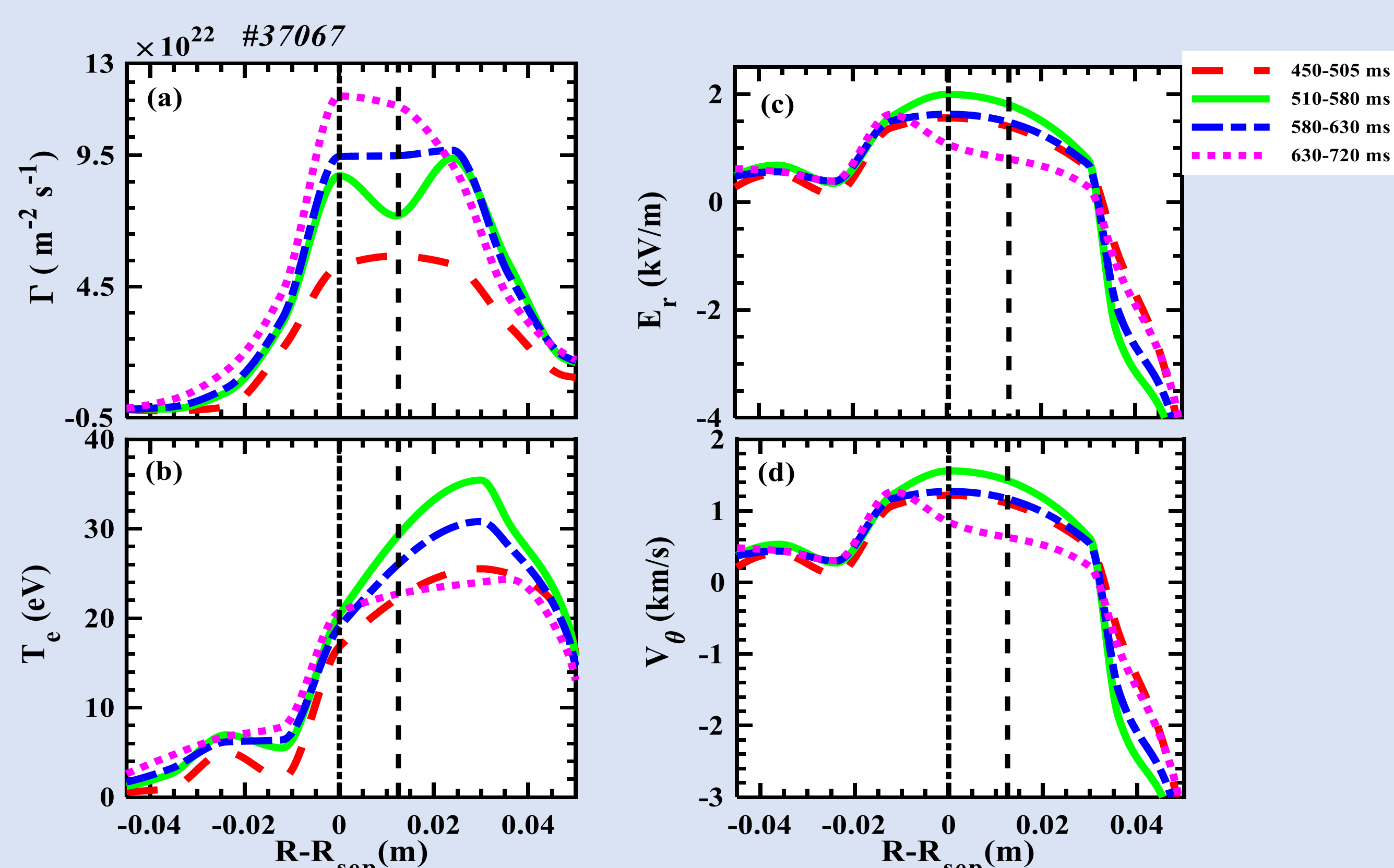


FIG. 3 The profiles of (a) saturation ion current density, (b) electron temperature, (c) the radial electric field, (d) poloidal $E \times B$ velocity on the outer divertor target.

PHYSICAL ANALYSIS

- ◆ **The estimation of the poloidal drift flow**

According to the Bohm-Chodura criterion [6]:

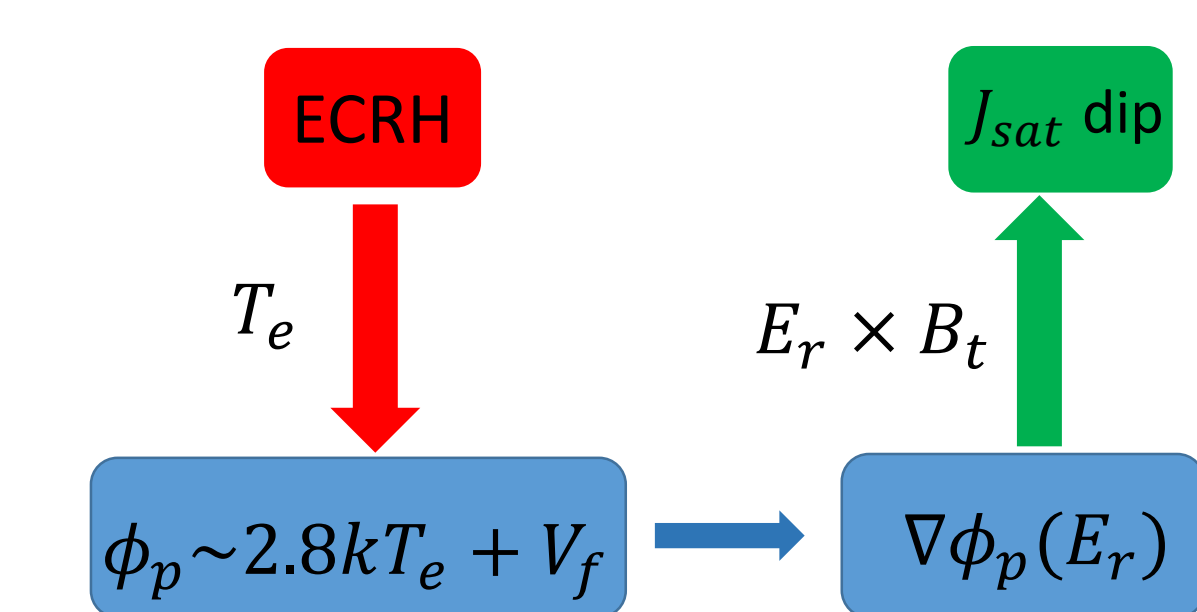
$$\sin\theta V_{||0} + \frac{\cos\theta E_r}{|B|} - \frac{\cos\theta \nabla P}{en|B|} = \sin\theta C_s \quad (1) \quad \frac{\cos\theta E_r}{B_t} = \frac{1.841 \text{ kV/m}}{1.275 \text{ T}} = 1.44 \text{ km/s}$$

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

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

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.

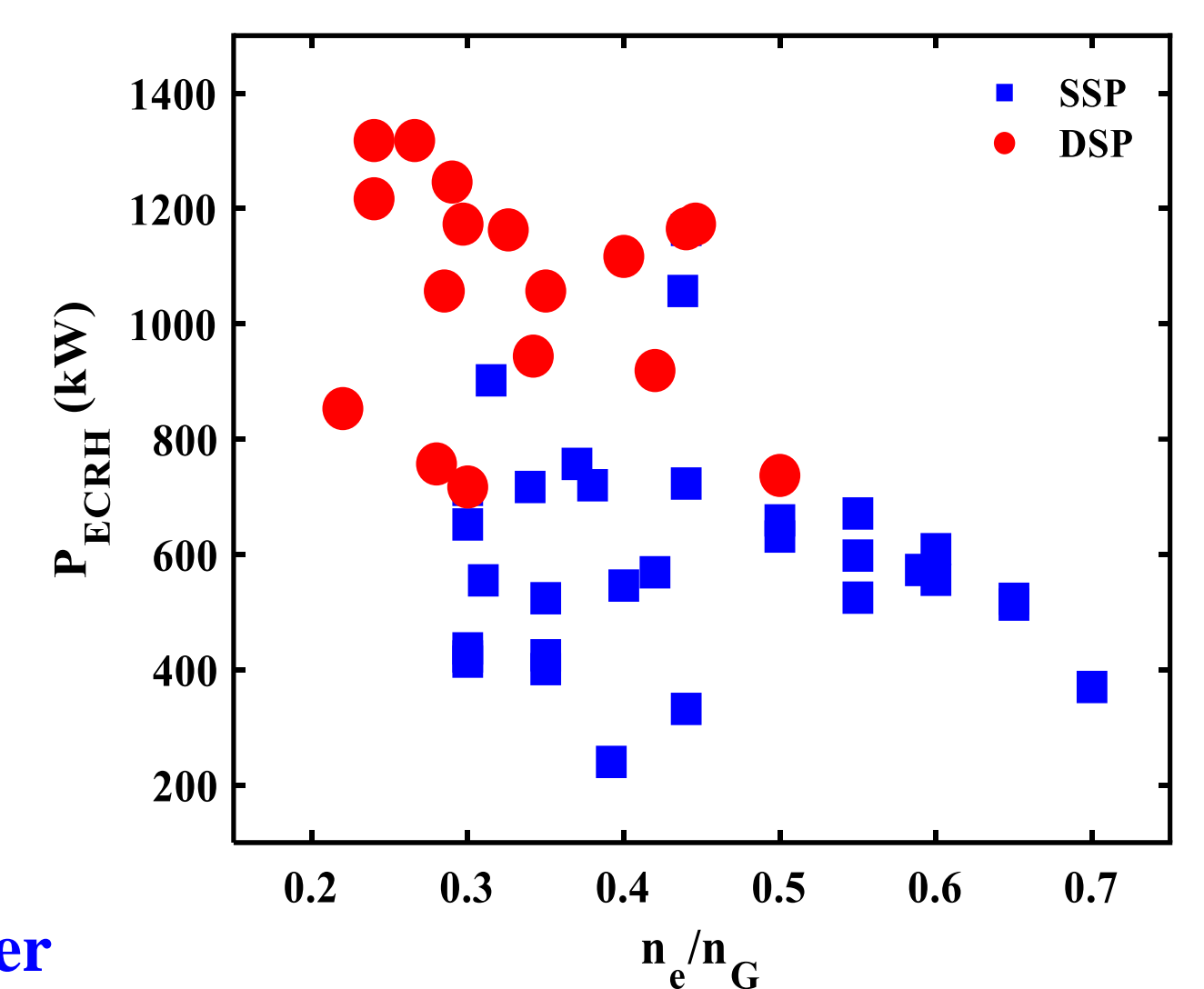


FIG. 4 The dependence of the DSP on the normalized electron density and the ECRH power

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.

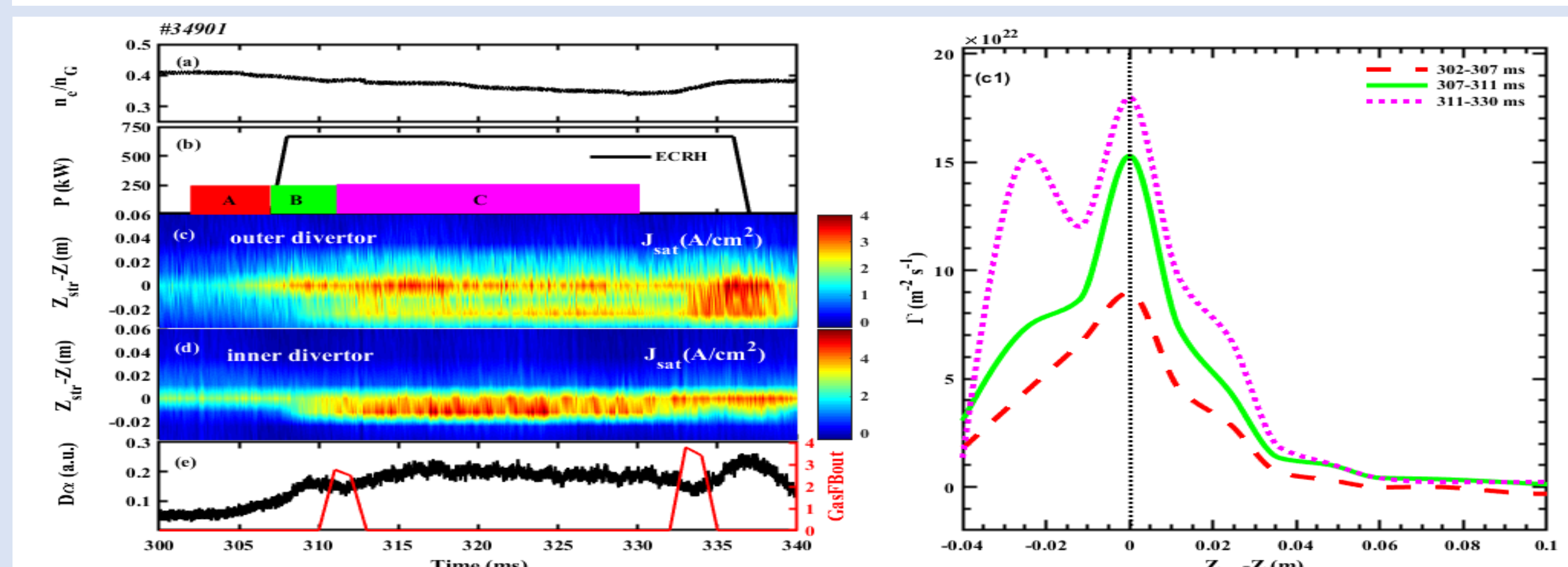


FIG. 5 The typical experiment observations of the DSP of the particle flux with density decrease during the ECRH plasmas

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 $E \times B$ 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 $E \times B$ 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.

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