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Study of light and heavy impurities transport in OH and ECRH plasmas on the T-10 tokamak

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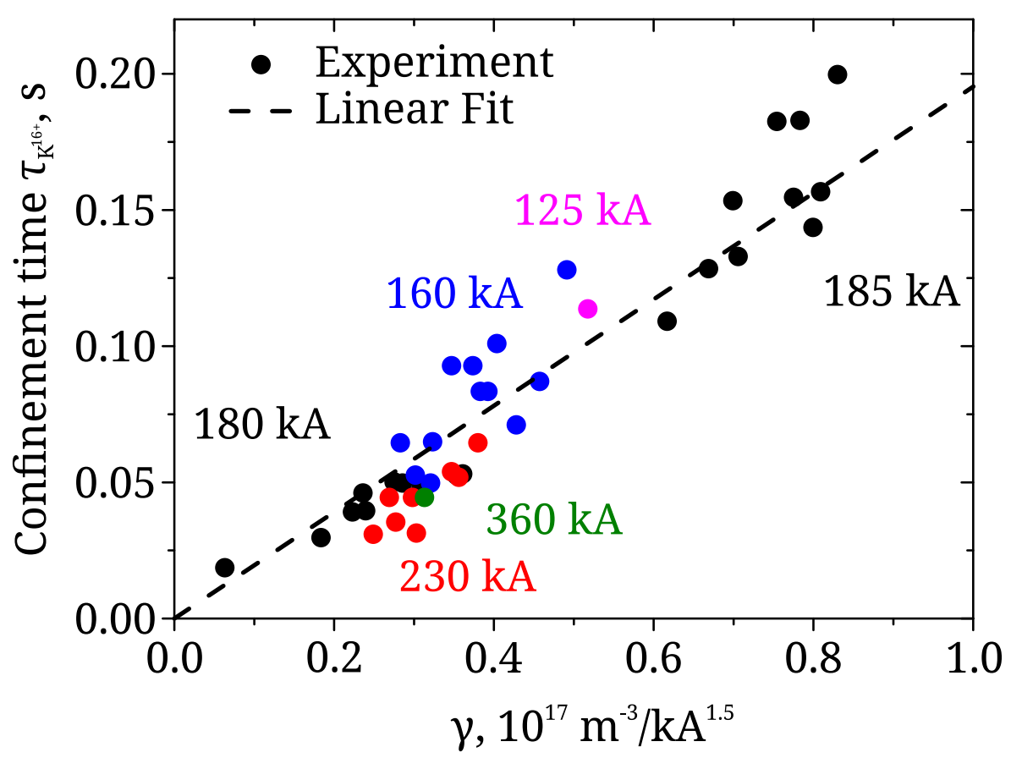
1. What do we know about light and medium impurity transport?

Impurity flux is considered as a sum of anomalous and neoclassical fluxes:

$$\Gamma_Z = \Gamma_Z^{neo} + \Gamma_Z^{an} \qquad \Gamma_Z^{neo} = -D_Z^{neo}\nabla n_Z + V_Z^{neo}\cdot n_Z \qquad \frac{V_Z^{neo}}{D_Z^{neo}} = \frac{Z}{Z_d}\left(\frac{\nabla n_d}{n_d} + \frac{H}{K}\frac{\nabla T_i}{T_i}\right)$$

$$\Gamma_Z^{an} = -D^{an}\nabla n_Z + V^{an}\cdot n_Z \qquad \frac{V^{an}}{D^{an}} = \frac{\nabla n_e}{n_e}$$



Anomalous transport coefficients $D^{an}(r)$ and $V^{an}(r)$ are obtained [1] by Ar and K injections:

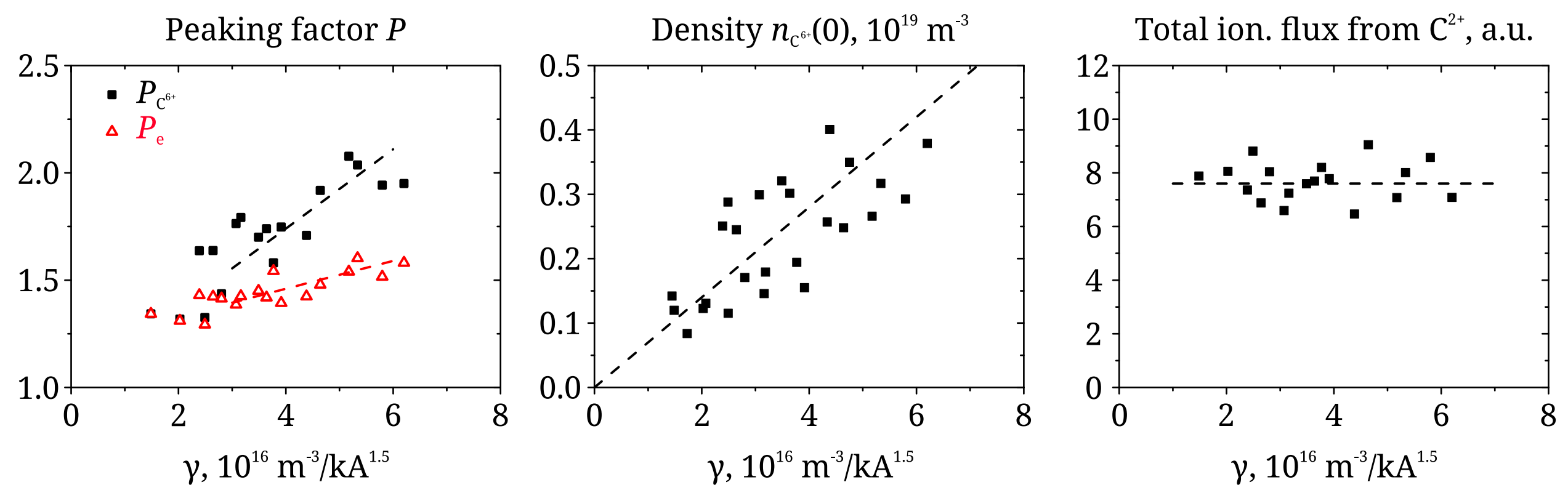
$$D^{an}(r) = 9\cdot10^{-4}\frac{I_{pl}^{1.5}}{n_e(r)\cdot Z_{eff}(r)}$$

$$V^{an}(r) = D^{an}(r)\cdot\frac{\nabla n_e(r)}{n_e(r)}$$

Impurity confinement can be characterized by parameter γ

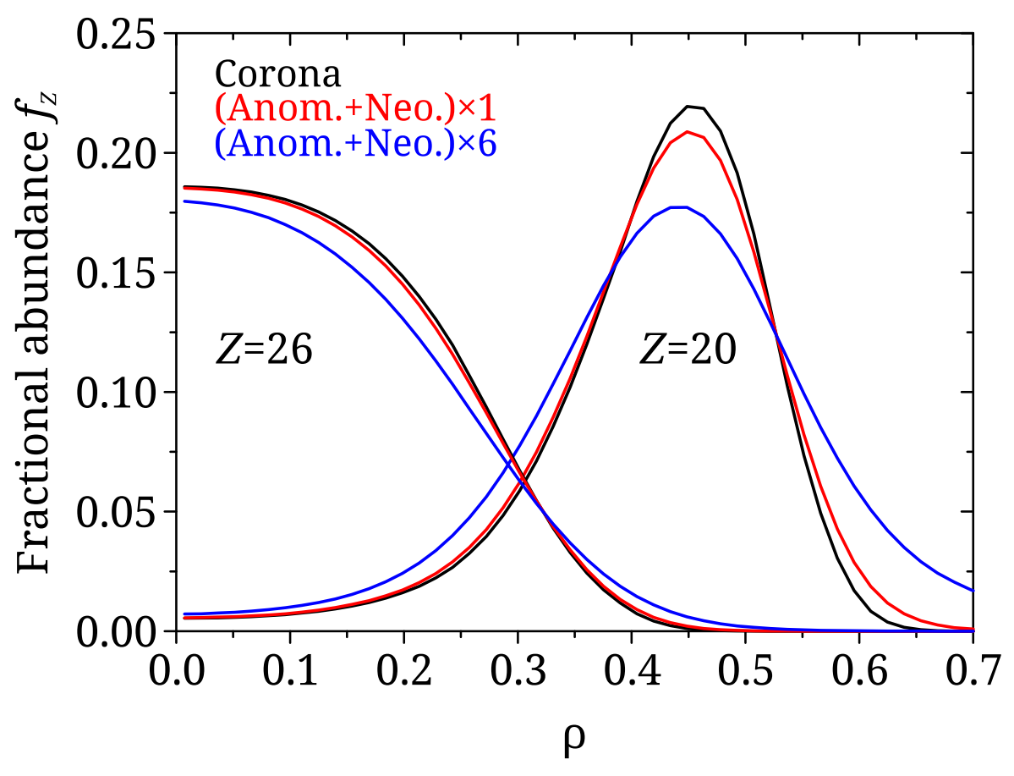
$$\gamma = \frac{\bar{n}_e\cdot\bar{Z}_{eff}}{I_{pl}^{\alpha}}, \quad \alpha = 1...2$$

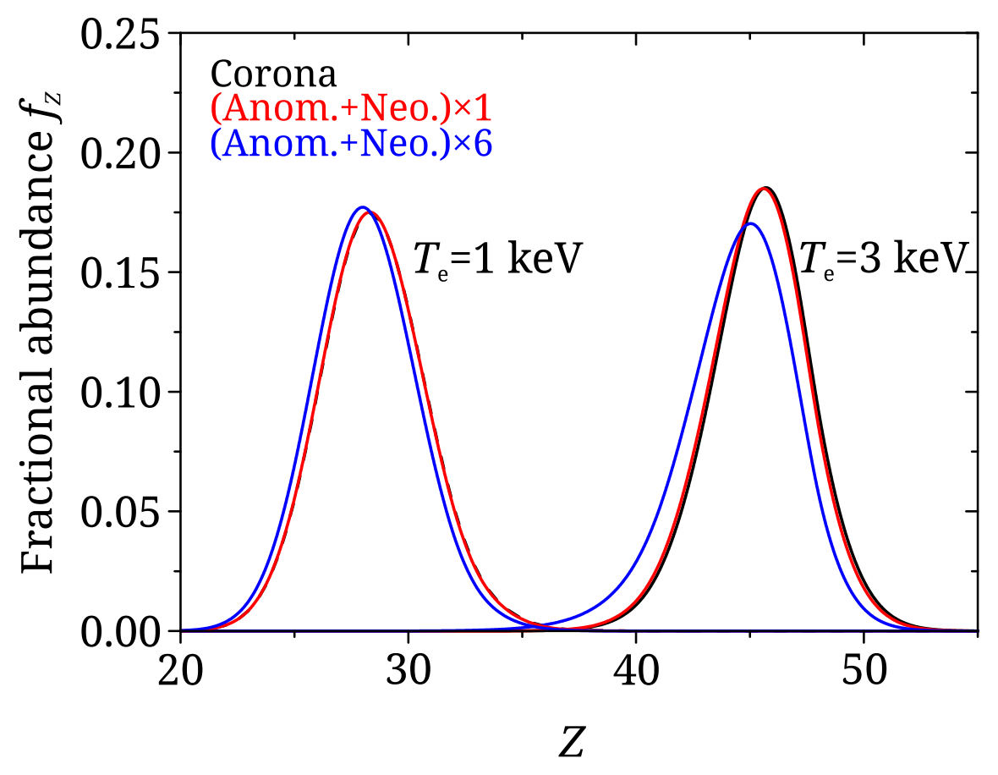
$$\Gamma_Z^{neo} \propto \gamma \qquad \Gamma_Z^{an} \propto 1/\gamma$$

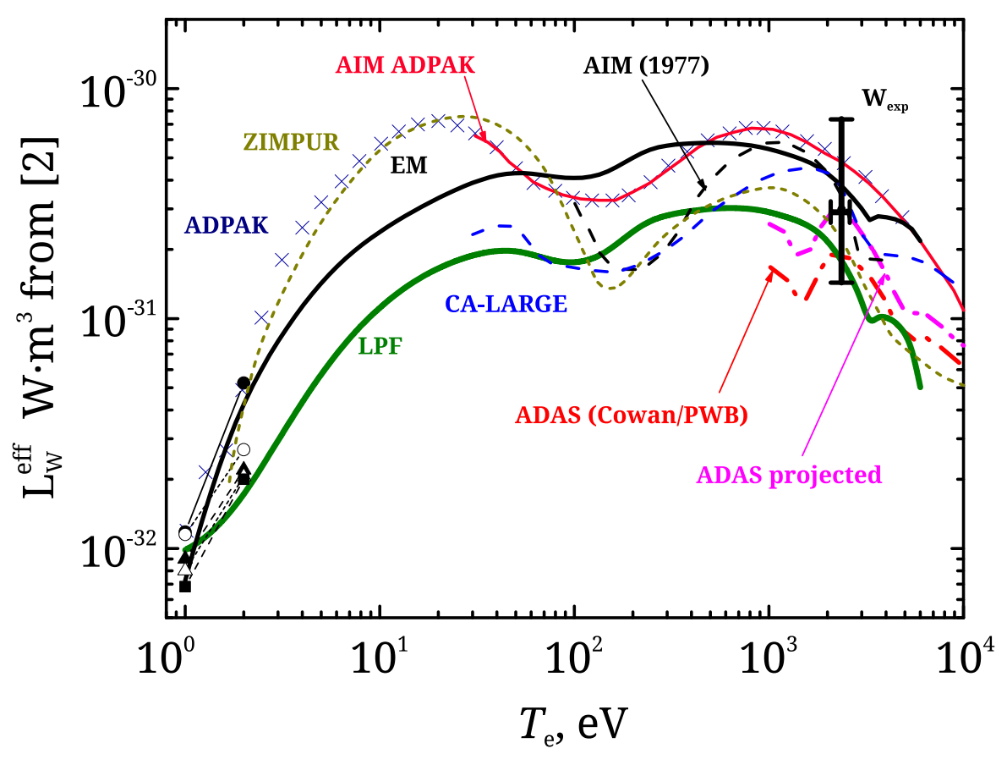


Would tungsten be described by this dependencies?

2. Determination of W density in T-10 experiments



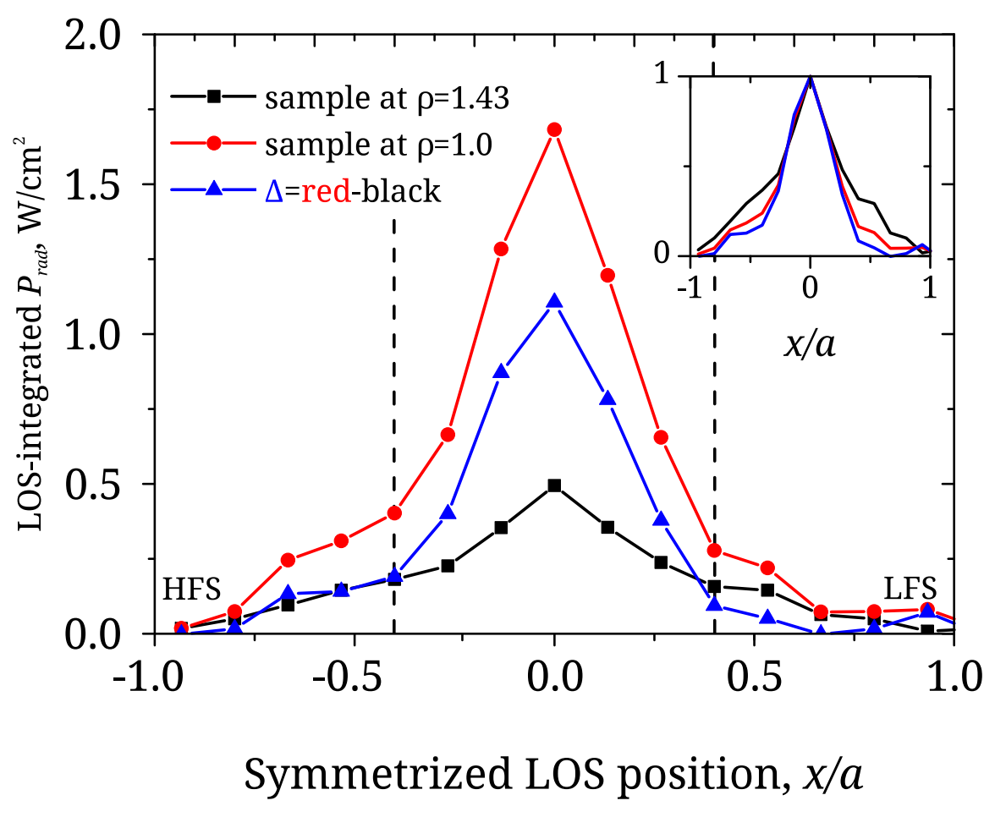




In order to use the integral AXUV diagnostics measuring total radiation of all impurity, we have to answer the following questions:

- Are fractional abundance of W ions on coronal radii?
- How reliable does W radiation stand out from the total emission of all impurities and where is it located?

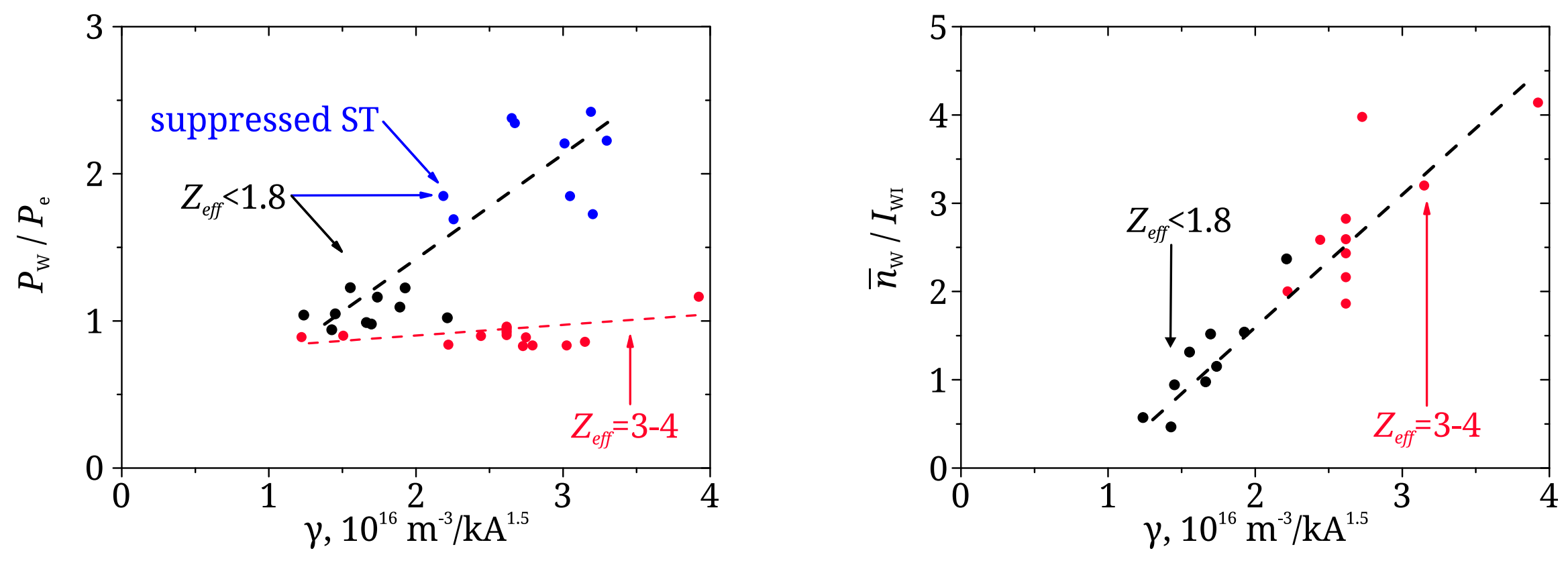
In OH and ECRH plasmas W ions are located on their coronal positions that allows using the effective cooling factor L_W^{eff} for tungsten ions in coronal equilibrium.

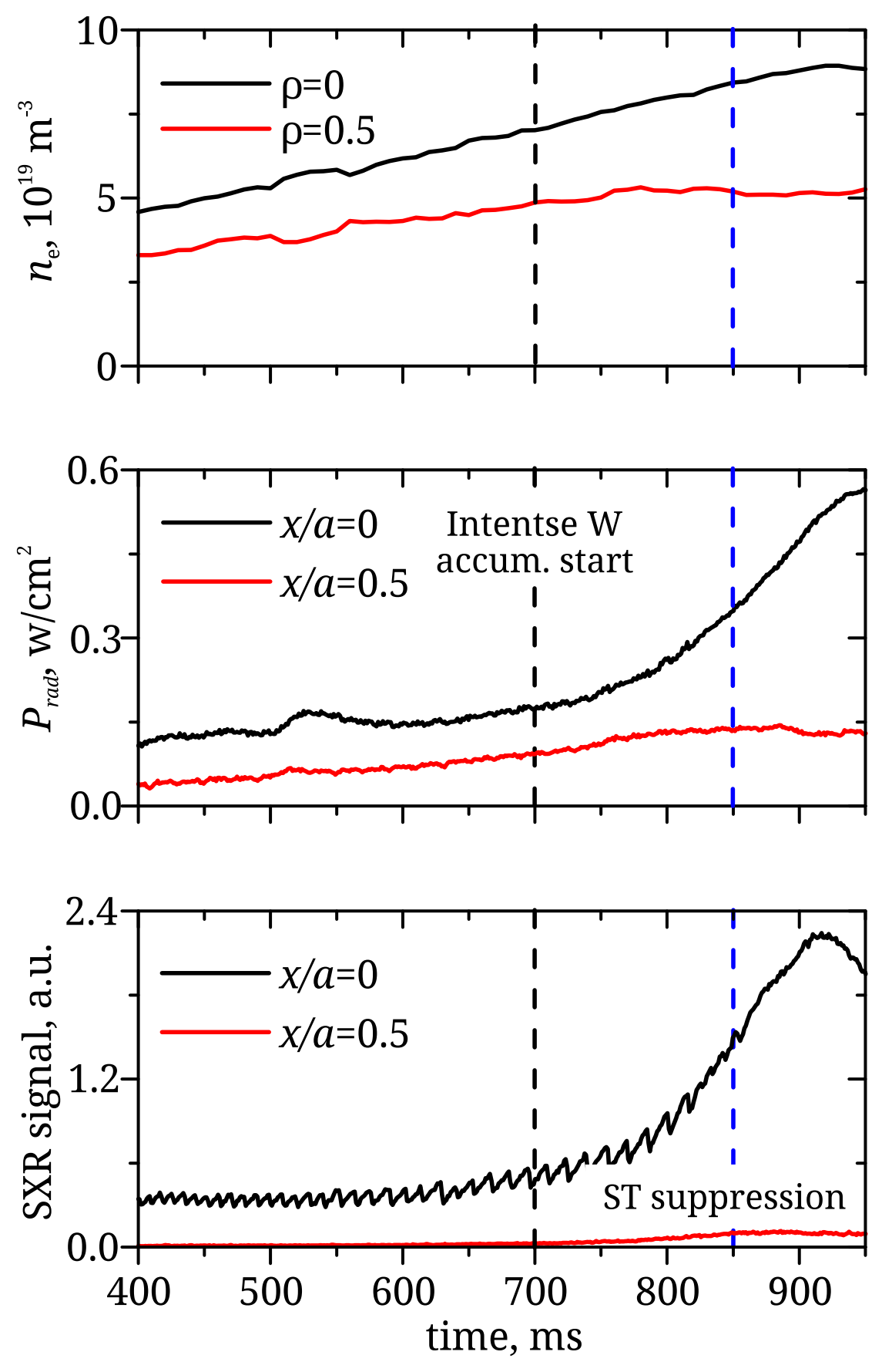


W total emission is located in zone |ρ|≤0.5

3. Tungsten behaviour in ohmic regimes

3.1 Comparison of W and light impurities transport properties





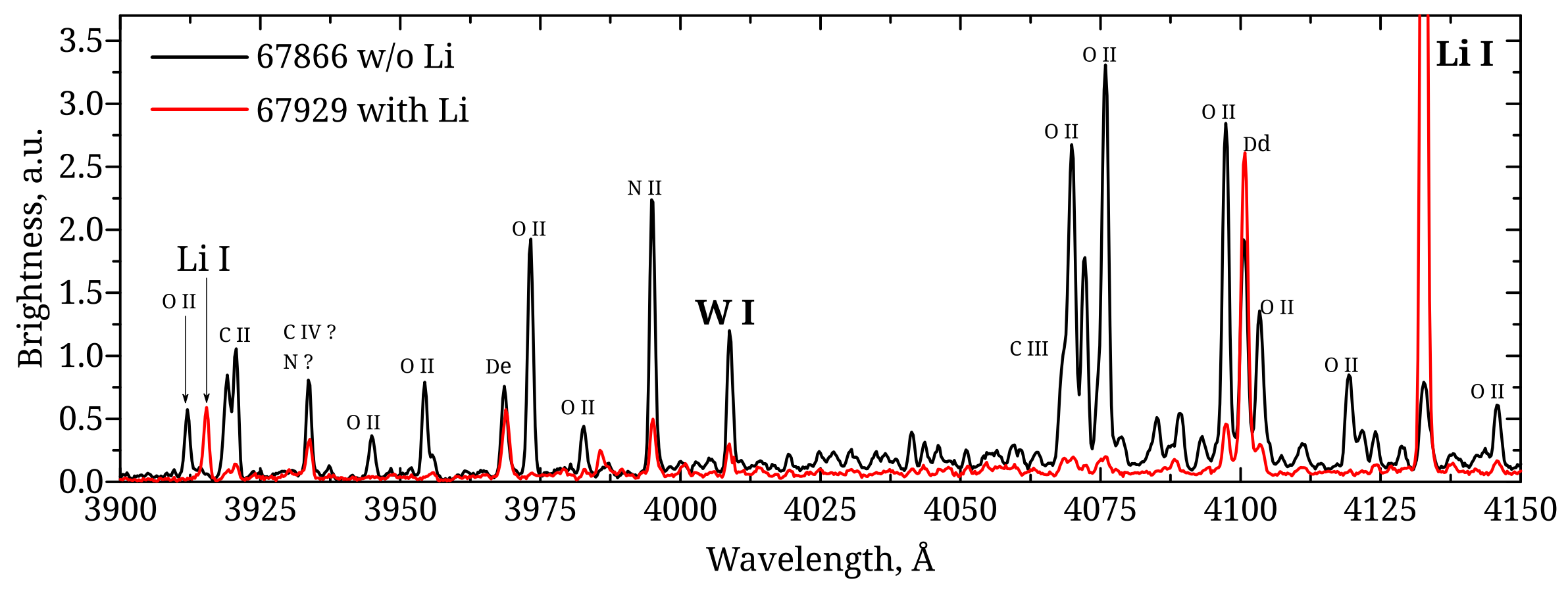
The accumulation is a joint process of the **peaking** and **cumulation**.

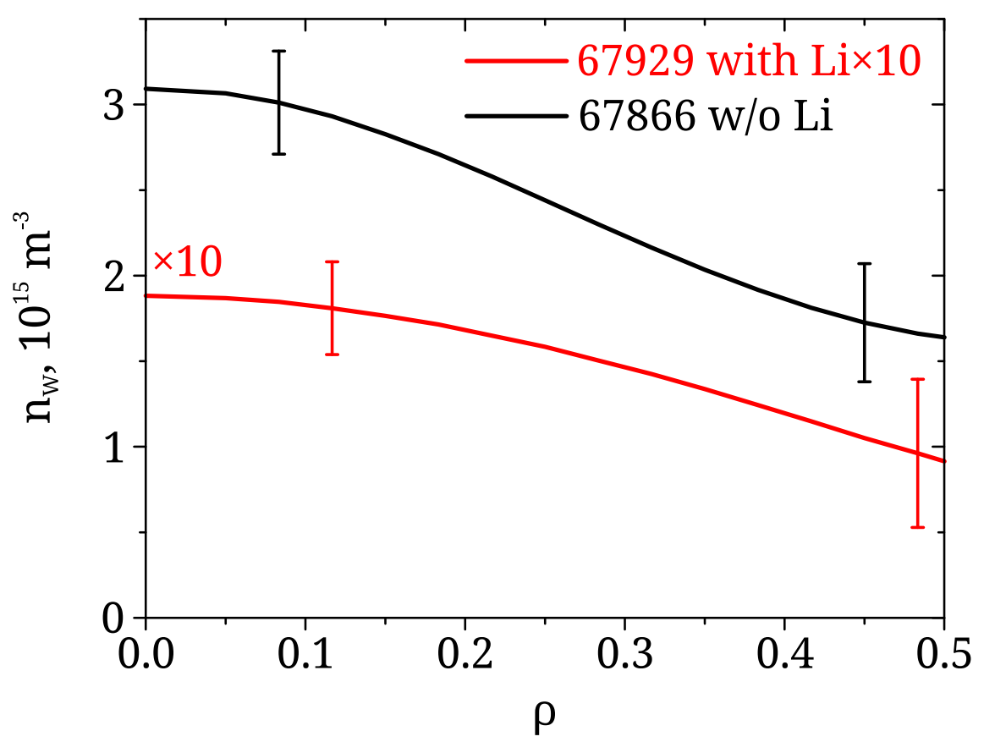
Peaking - narrowing of W density profile. Characterized by $P_W = n_W(0)/\bar{n}_W$
Cumulation - integral increase of W density without its profile changes. Characterized by $\bar{n}_W/I_{WI}$.

W density peaking increases with γ growth that is explained by $\Gamma_W^{neo}\sim\gamma$ while for light impurities - by $\Gamma^{an}\sim1/\gamma$.

In high-Z_{eff} plasma W is highly cumulated and weakly peaked
In low-Z_{eff} plasma W is highly peaked and weakly cumulated

3.2 Differences of W accumulation processes in high- and low-Z_{eff} plasmas





Low-Z_{eff} plasma is obtained by means of the Li-limiter. Li covers the surface of the W-limiter that leads to the W influx decrease confirmed by WI emission reduction.

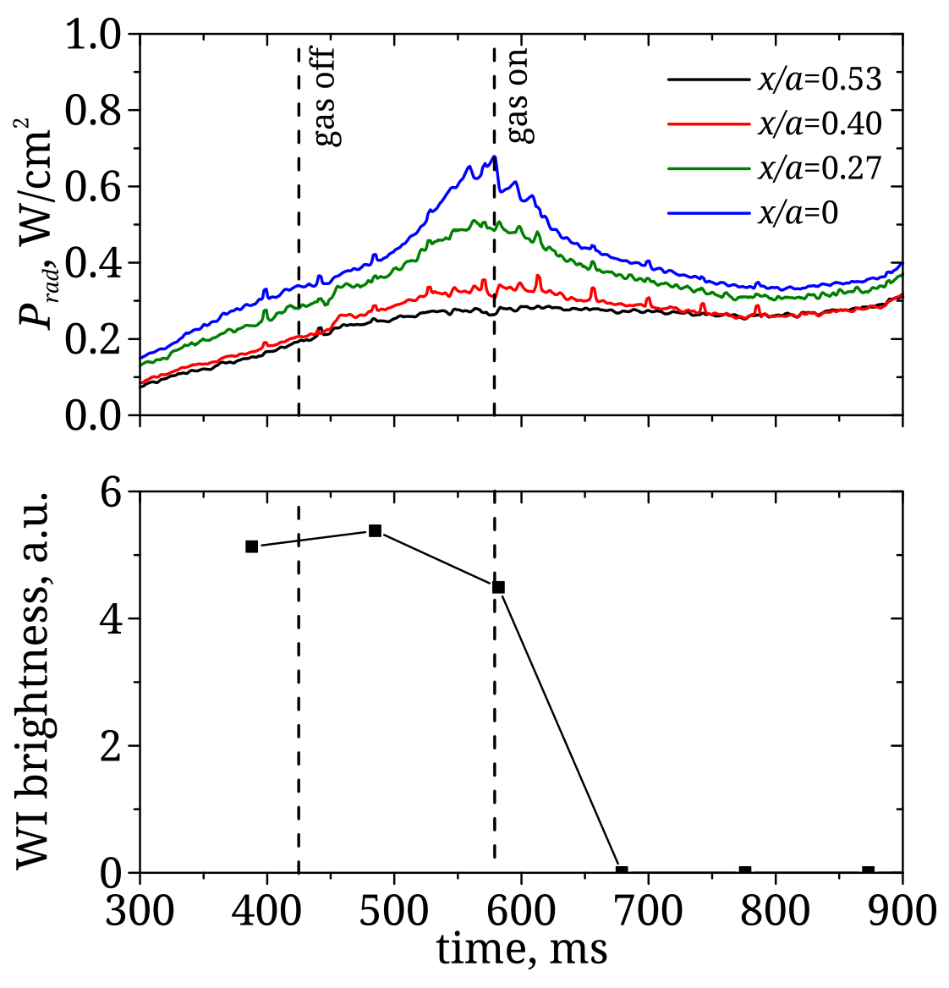
Light impurities C, N, O are gettered by lithium. Removal of C and O results in the transition to the low collisionality plasma with $Z_{eff}\approx1$ where anomalous transport dominates over the neoclassical one. The W accumulation is suppressed in conditions of enhanced anomalous transport.

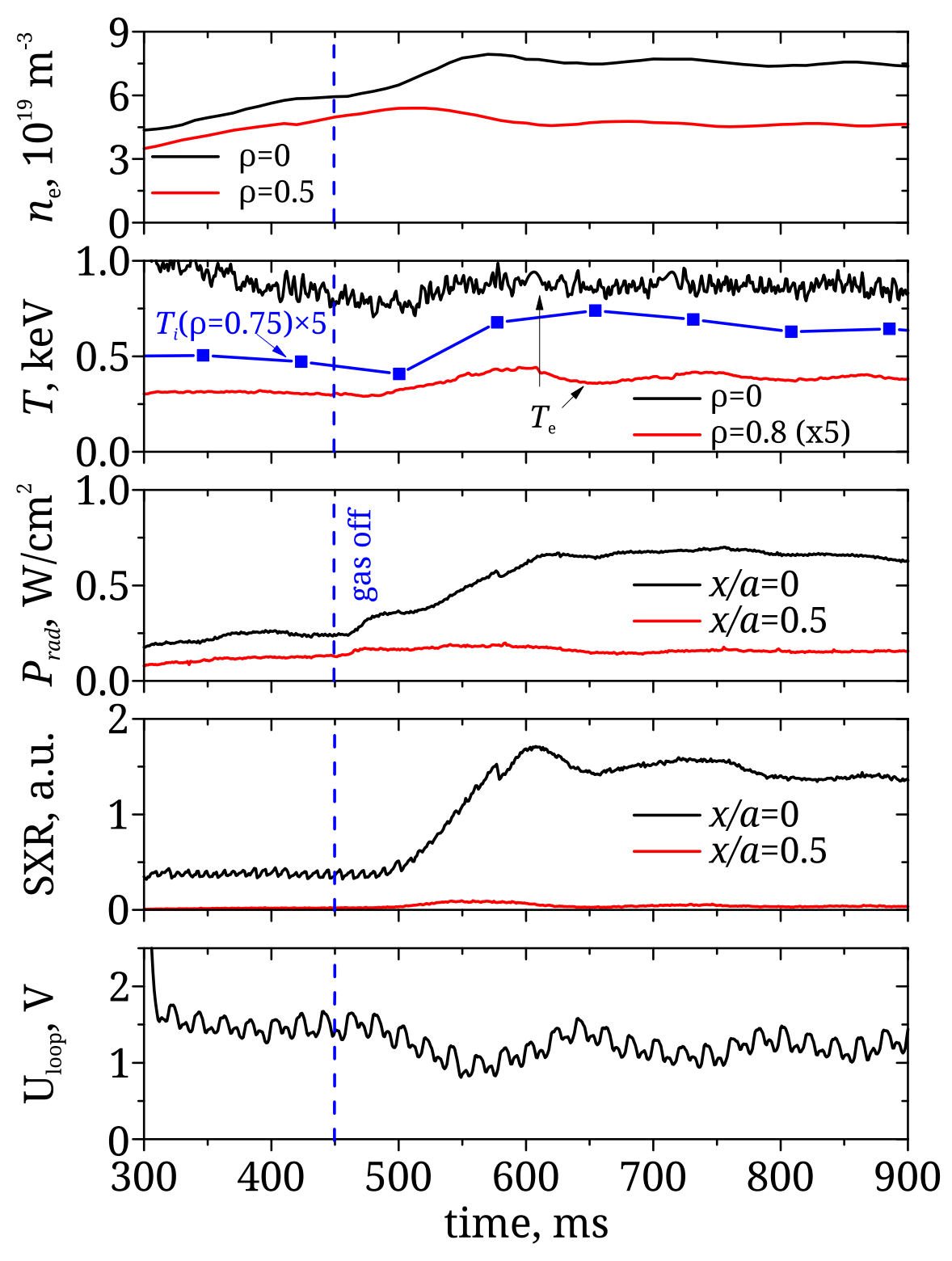
W density in the center in low-Z_{eff} plasma in reduced by 10-20 times in regards to high-Z_{eff} plasma

3.3 Gas puffing influence on W accumulation process in lithized discharges

The W accumulation can be simply controlled by deuterium gas puffing in discharges with lithized walls.

Gas off	Gas on
n_e, n_d - peaking	n_e, n_d - flattening
T_e, T_i - flattening	T_e, T_i - peaking
source W ↑?	source W ↓



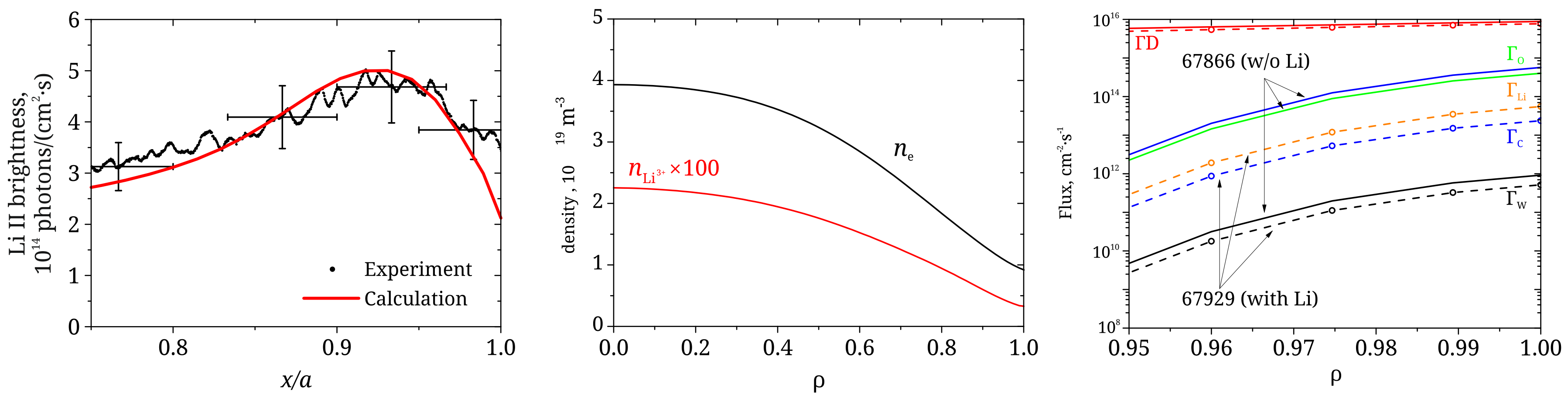


Processes initiated by the switching gas puff off intensify the W accumulation. The switching gas puff on causes the opposite changes of n_e, T_e, T_i that leads to W de-accumulation.

In high-Z_{eff} plasmas unlike low-Z_{eff} gas puffing does not significantly influence on W accumulation process.

4. Features of Li-limiter on T-10

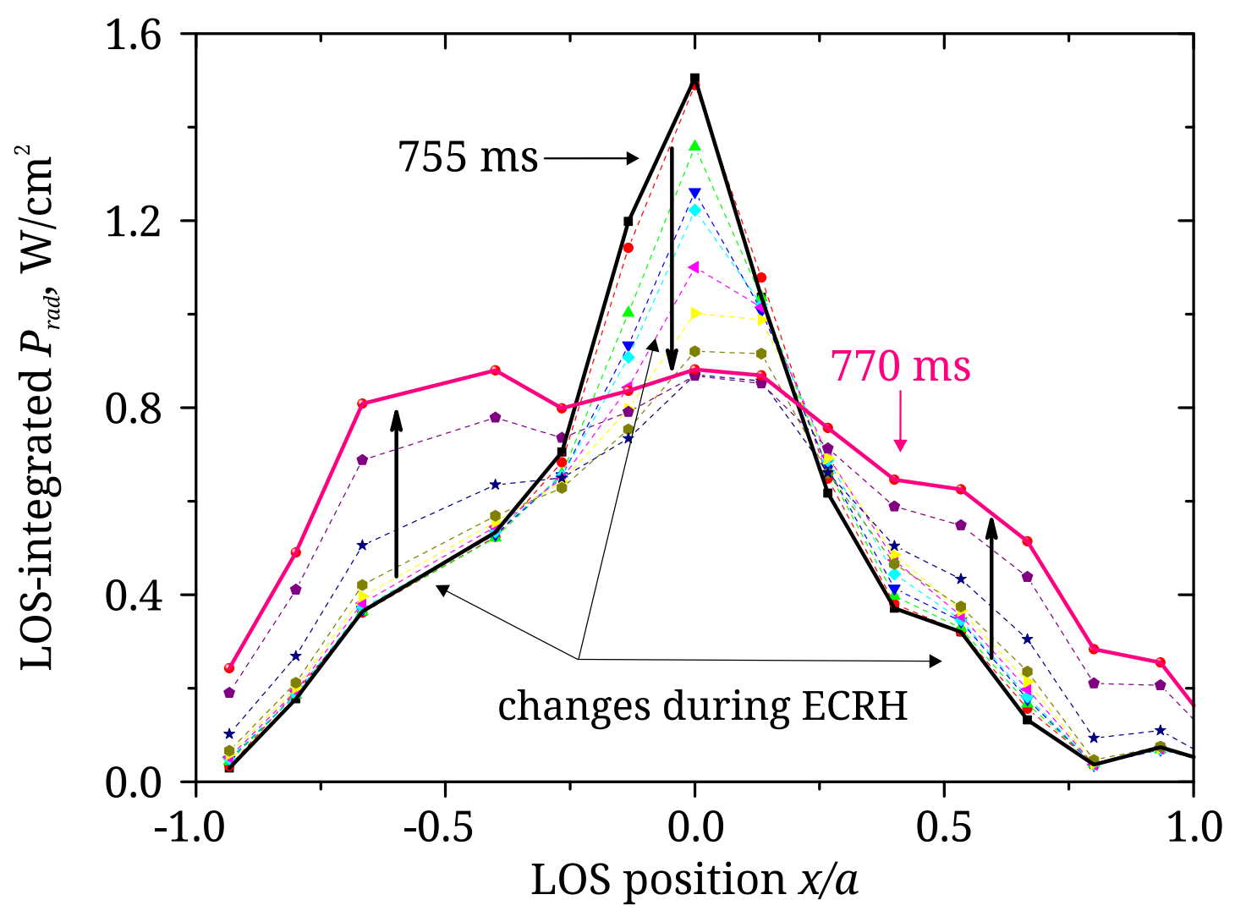
High intense emission of Li II 5485 Å is registered while no lithium nuclei are observed by the CXRS diagnostics (lower than sensitivity 0.3% of n_e). The description of Li II brightness profile in absolute values in STRAHL transport code provides Li influx $\Gamma_{Li}=5.5\cdot10^{17}$ m^{-2}·s^{-1} what is lower than C and O influxes in non-lithized discharges and confirms low level of Li^{3+} density.

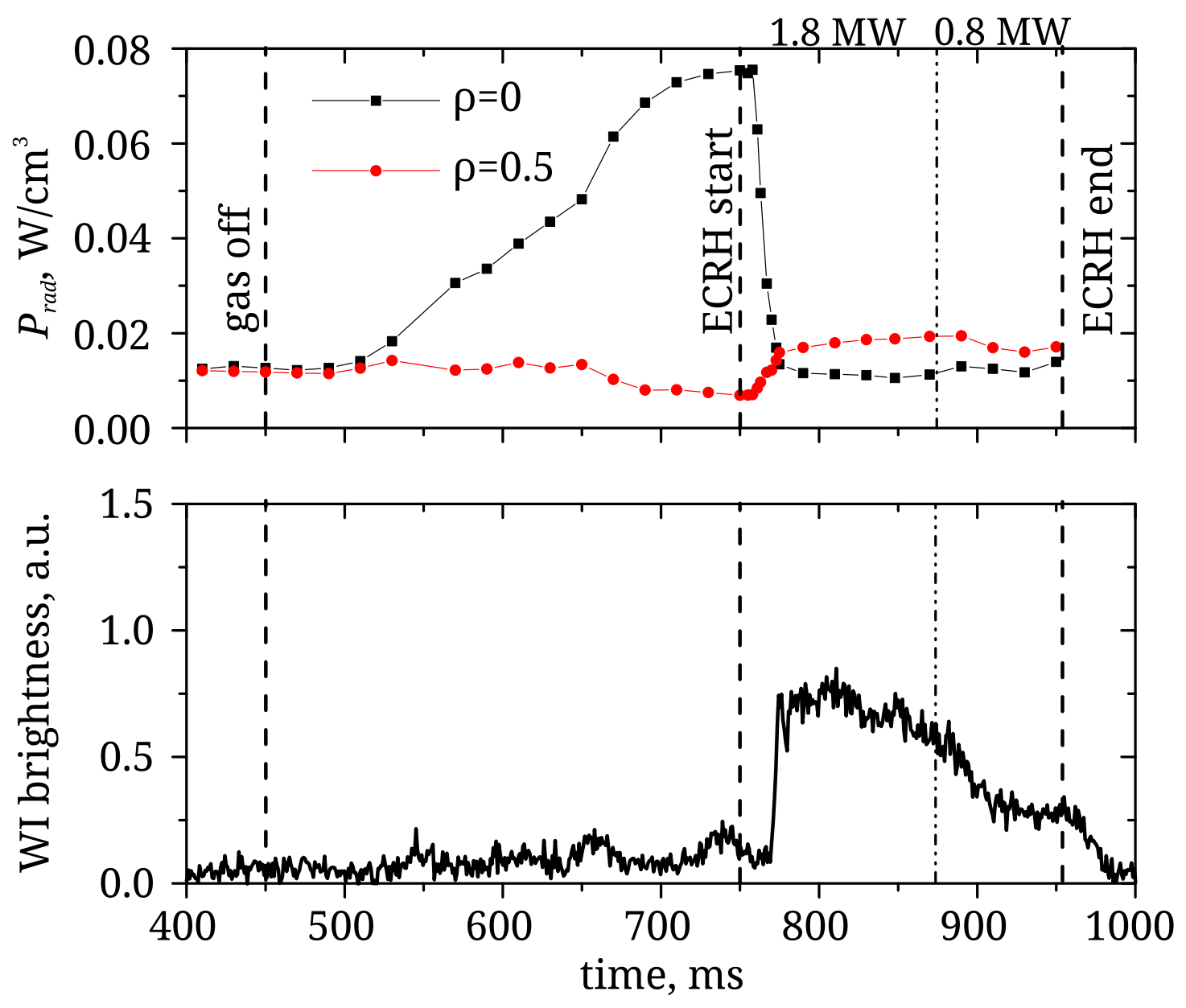


5. ECRH regime

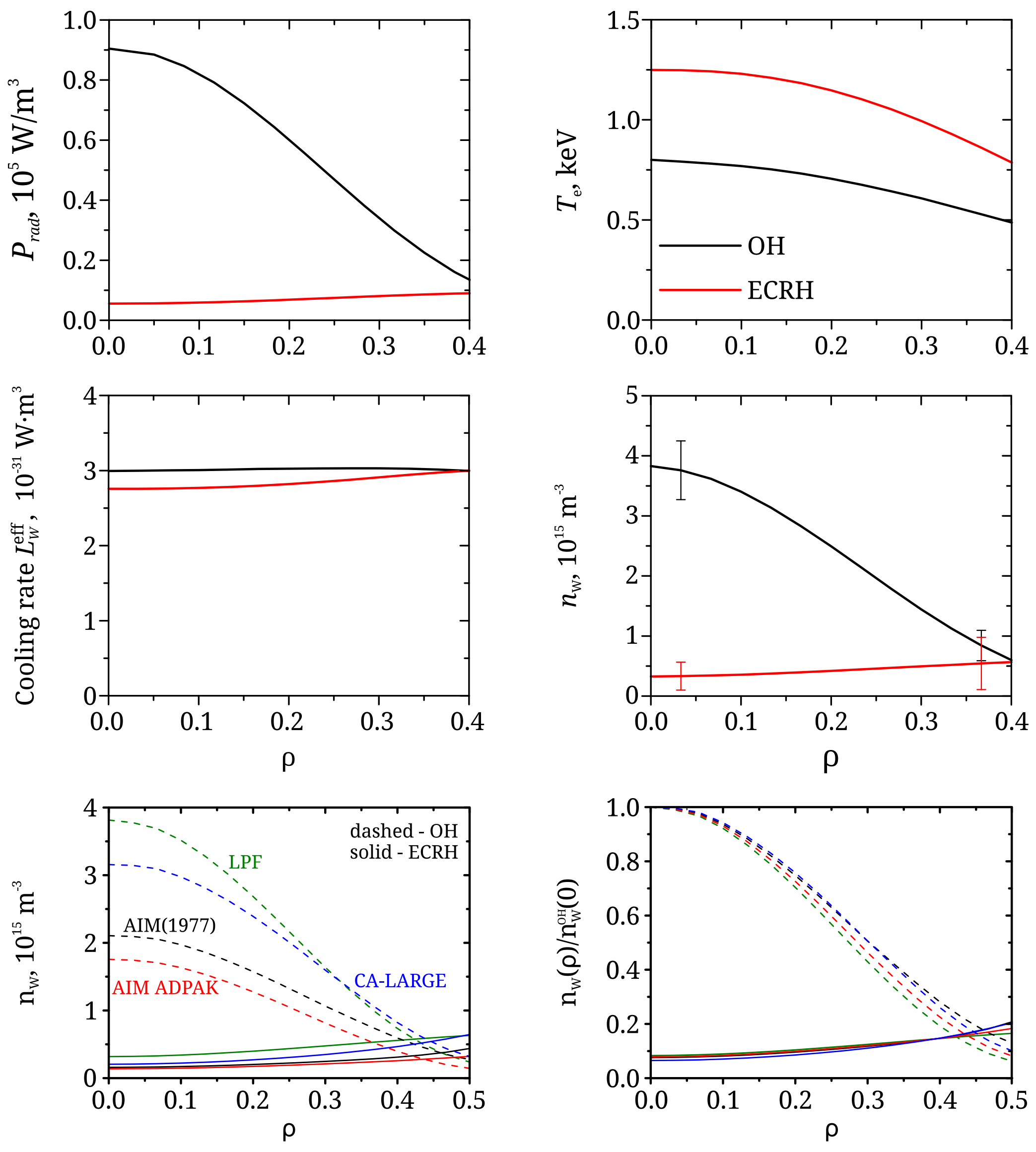
The W removal process proceeds together with the increase of WI emission that indicates the growth of W influx on the circle limiter during the ECRH. The rapid decrease of radiation in the center and its growth at the periphery occur. The radial AXUV profile changes drastically what is determined mainly by the W removal and far less by n_e and T_e variation.

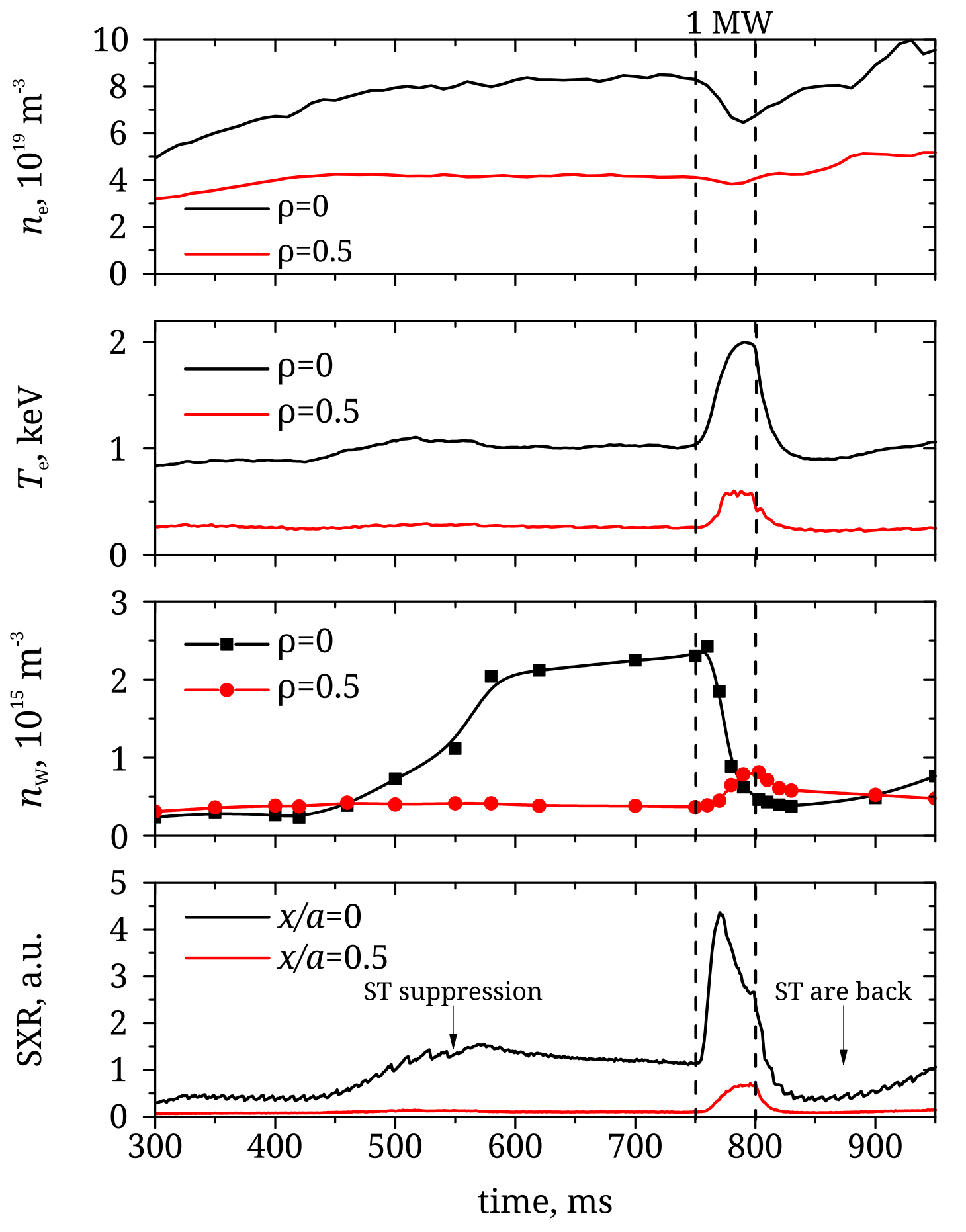
The W removal occurs at the saw-teeth free stage of the discharge 68037 and the ECRH does not lead to an increase of saw-tooth activity. It indicates that the removal is produced principally by the rise of anomalous transport rather than saw-tooth oscillations.





W removal from plasma center is more efficient than light impurities [4] even considering the spread of $L_W^{eff}(T_e)$ dependencies





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