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STUDY OF THE ECR-HEATING INFLUENCE ON THE ANOMALOUS TRANSPORT OF TUNGSTEN IONS IN T-10 PLASMA

I.A. Zemtsov, V.A. Krupin, M.R. Nurgaliev, L.A. Klyuchnikov, A.R. Nemets, A.Yu. Dnestrovskiy, A.A. Borschegovskiy, T.B. Myalton, D.V. Sarychev, D.S. Sergeev, N.A. Solovev, G.F. Subbotin
NRC “Kurchatov Institute”
zemtsov_ia@nrcki.ru

ABSTRACT

- In the experiments on T-10 with the electron-cyclotron resonance heating tungsten was removed from the center of the plasma column.
- The transport model to estimate the tungsten transport coefficients in the cases when the removal took place according to the exponential law by prediction of the experimental dynamics is coded using the STRAHL code integrated in the ASTRA code
- For selected discharge, the calculated characteristic decay time is τ_{exp}≈14 ms, diffusion is at the level of 1.5 to 2 m^2/s higher then the ohmic level and the pinch term in this case is neglectable up to the middle of the plasma column.

METHOD OF TUNGSTEN REMOVAL MODELING

The tungsten inflow into the discharge is estimated from the brightness of the WI atom line λ=4001 Å at the W-limiter region. The density of tungsten ions within a/2 is determined from the integrated radiation losses power P_W^{rad} recorded by AXUV-diagnostics. The preservation of coronal equilibrium for T-10 conditions in ohmic and ECR regimes makes it possible to determine the total tungsten ions density profile $n_W(r)=\sum n_i(r)$ from the expression:

$$P_W^{rad}(r)=n_e(r)L_W^{eff}(r)\sum_i n_i(r),$$

where L_W^{eff} is the tungsten cooling factor.

In discharges where the W removal is exponential (shown in Fig. 1), the description of the AXUV-signal experimental dynamics in the region from 0 to a/2 in the transport model allows one to estimate the transport coefficients of W ions. For this purpose, a system of two continuity equations (dynamic and stationary) is solved:

$$\begin{cases}\dfrac{\partial n_W(r,t)}{\partial t}+\operatorname{div}\left[-D(r)\cdot\nabla n_W(r,t)+V(r)\cdot n_W(r,t)\right]=Q_W(r,t),\\ \operatorname{div}\left[-D(r)\cdot\nabla n_W(r)+V(r)\cdot n_W(r)\right]=Q_W(r),\end{cases}$$

where D and V are the desired diffusion coefficient and pinch velocity, Q_W is the sum of sources and sinks (Q_W≈0 for the central region of the plasma due to the presence of W ions coronal equilibrium). The solution is carried out by choosing $D(r)$ and $V(r)$ that allow us to describe the temporal behavior of the tungsten radiation profile recorded by the AXUV detector in the best way.

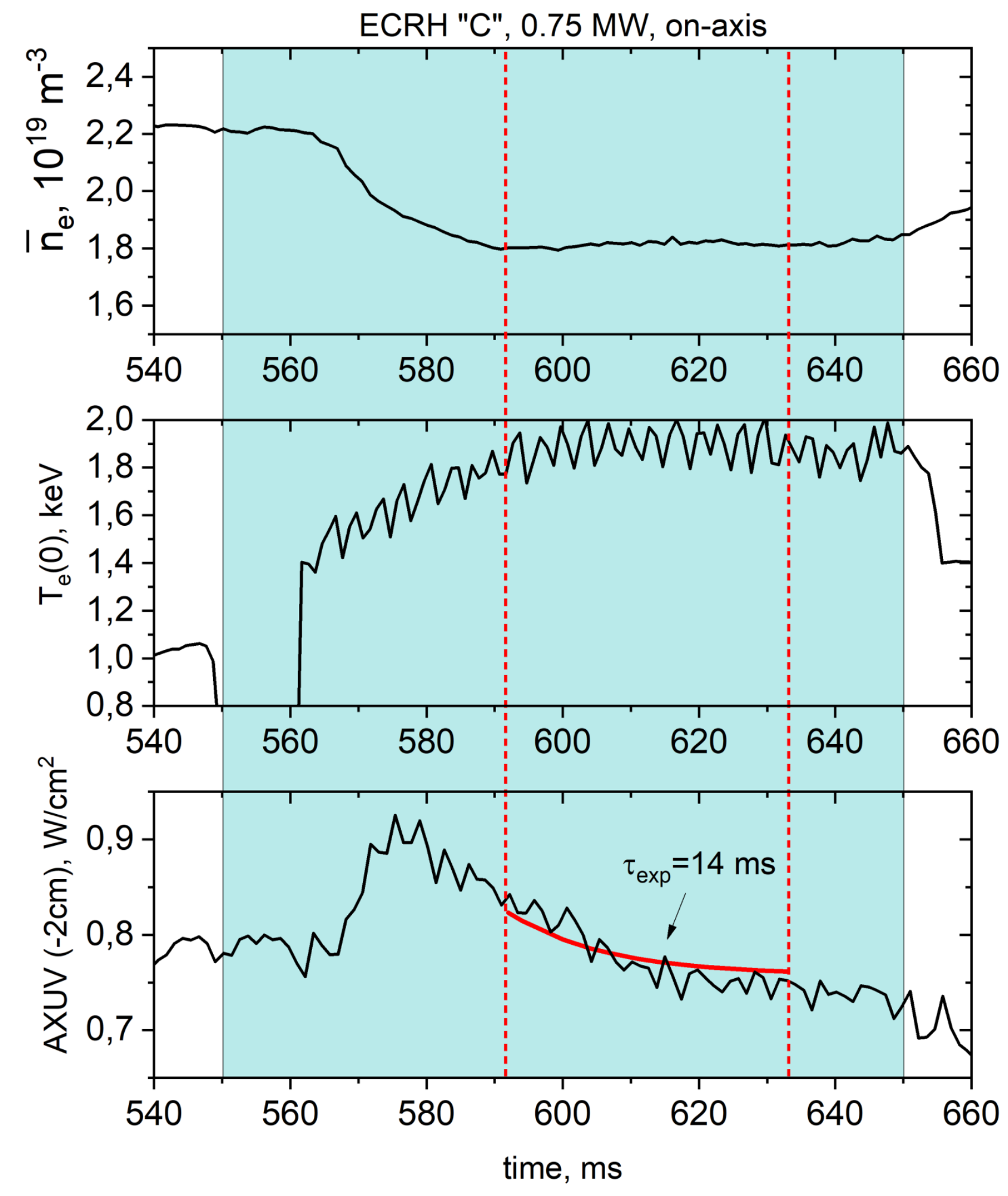

FIG. 1. Tungsten removal scenario in discharge 70358: I_{pl} = 220 kA, P_{EC} = 0.75 MW (on-axis, co-ECCD)

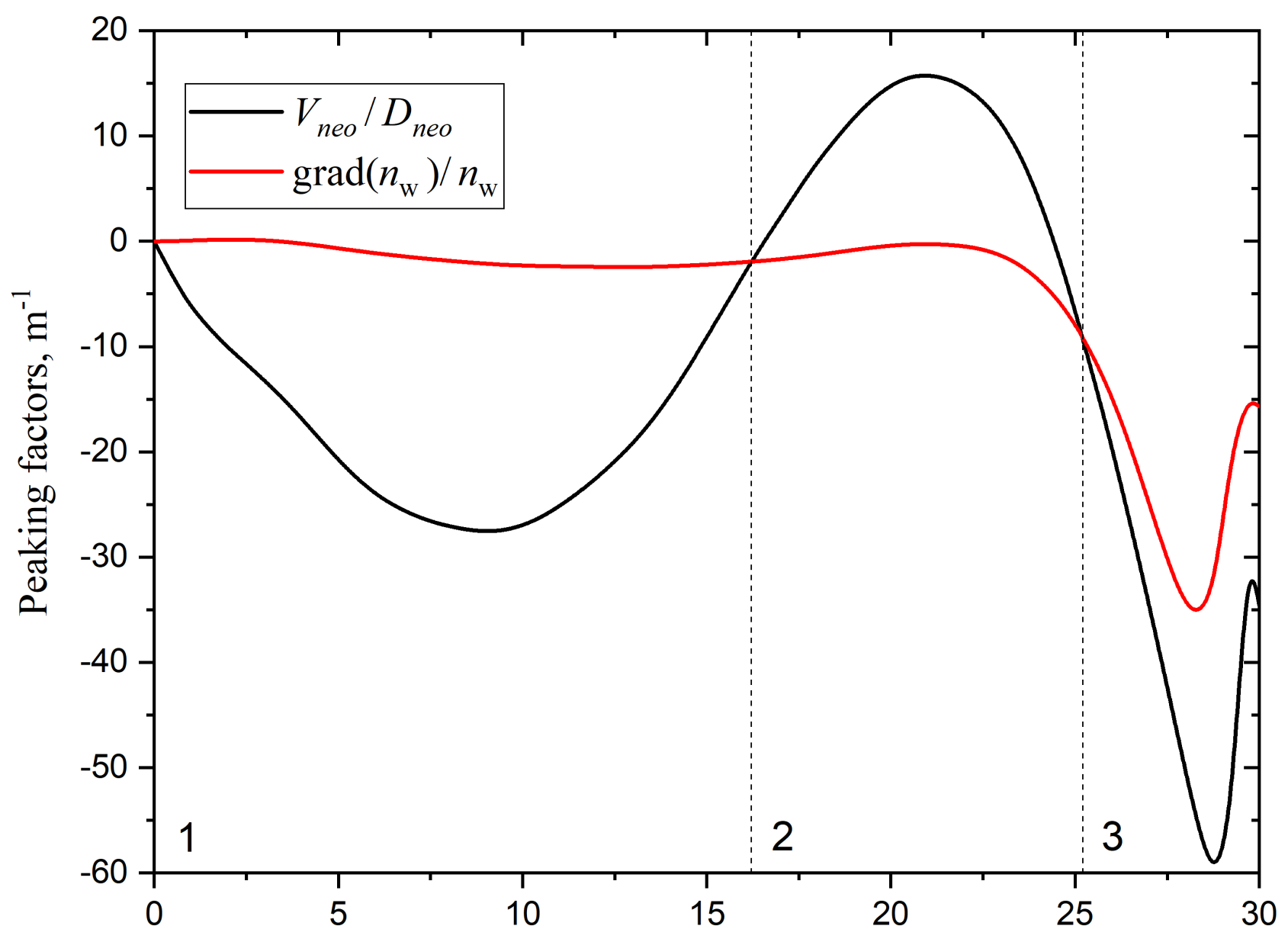

FIG. 2. Peaking factors in discharge 70358 at t=590 ms

This system is solved using the STRAHL code integrated in the ASTRA code. Transport coefficients are considered as the sum of neoclassical and anomalous components: $D=D_{neo}+D_{an}$ and $V=V_{neo}+V_{an}$. The neoclassic ones are calculated using the NEOART code. The anomalous coefficients are matched from the expressions (2):

$$D^{an}=\frac{k_{D1}}{n_e(r)}\cdot\frac{r^2}{a^2}+k_{D2}\exp\left[-\left(\frac{r-b_D}{c_D}\right)^2+d_D\right],$$

$$V^{an}=\frac{k_{V1}}{n_e^{\,2}(r)}\cdot\frac{r^2}{a^2}\cdot\frac{\partial n_e(r)}{\partial r}+k_{V2}\exp\left[-\left(\frac{r-b_V}{c_V}\right)^2+d_V\right],$$

where the coefficients b_i, c_i, d_i, and k_i are the free parameters that are varied until the resulting modelled tungsten removal dynamics matches experimental data. Such large set of free parameters is hard to handpick. To simplify the process the peaking factors were introduced. The continuity equation for Γ_W = 0 shows that

$$\frac{\nabla n_W}{n_W}=\frac{V_{neo}+V_{an}}{D_{neo}+D_{an}}.$$

Therefore, the relation between and V_{neo}/D_{neo} (the peaking factors) shows how the V_{an} and D_{an} might be variated to get a better fit. On the Fig. 2 the regions 1 and 3 have V_{neo}/D_{neo}< $\nabla n_W/n_W$ and the increasing of Dan can bring us closer to an equilibrium (3). The region 2 have V_{neo}/D_{neo}>$\nabla n_W/n_W$ and the decreasing of V_{an} helps to match the experimental data.

RESULTS OF THE CALCULATIONS

Finding a set of free coefficients a_i, b_i, c_i, d_i, and k_i that fits the experimental data is a very time-consuming task that was successfully performed for just one discharge with the following parameters: I_{pl}=220 kA, on-axis, co-ECCD ECR heating with P_{EC}=0.75 MW, sawtooth oscillations and m=2 mode are present. The decay description in this discharge is shown in Fig. 3 with a red line. The modeled dynamics fits well with the experimental data for the radii from 0 up to a/2 where the reliability of the used method to determine n_W is high.

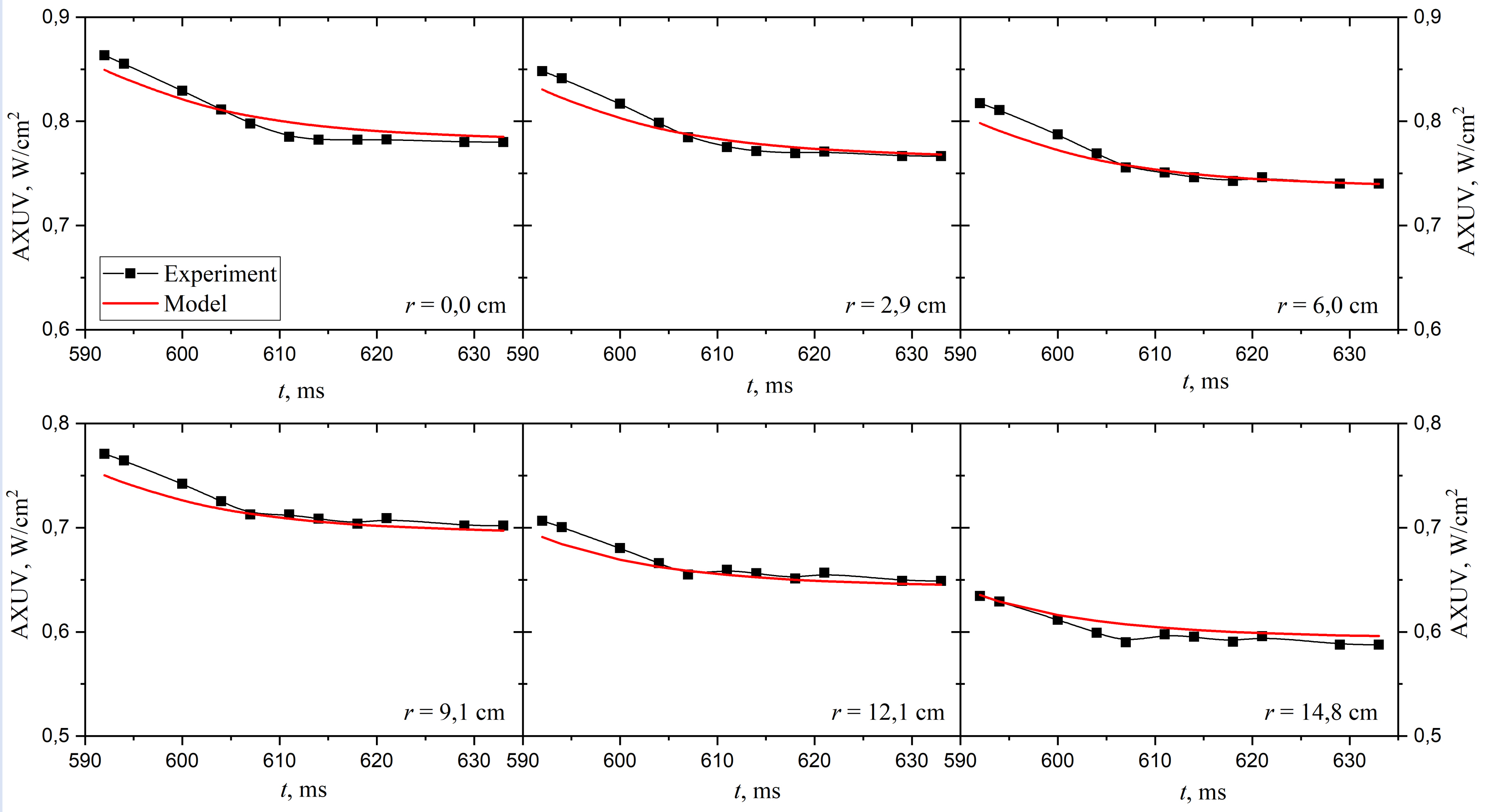

FIG. 3. Tungsten removal description in the model for discharge 70358

The profiles of the anomalous transport coefficients in ECR mode and their comparison with the OH mode and neoclassical components is presented on the Fig. 4. The characteristic decay time in the processed discharge is τ_{exp}≈14 ms. This time can be obtained by adding diffusion to the 1.5 – 2 m^2/s over the ohmic level. The pinch term in this case turns out to be practically zero at radii up to the a/2. Thus, the introduction of on-axis ECR-heating leads to the tungsten removal from the plasma center mainly due to an increase in its anomalous diffusion.

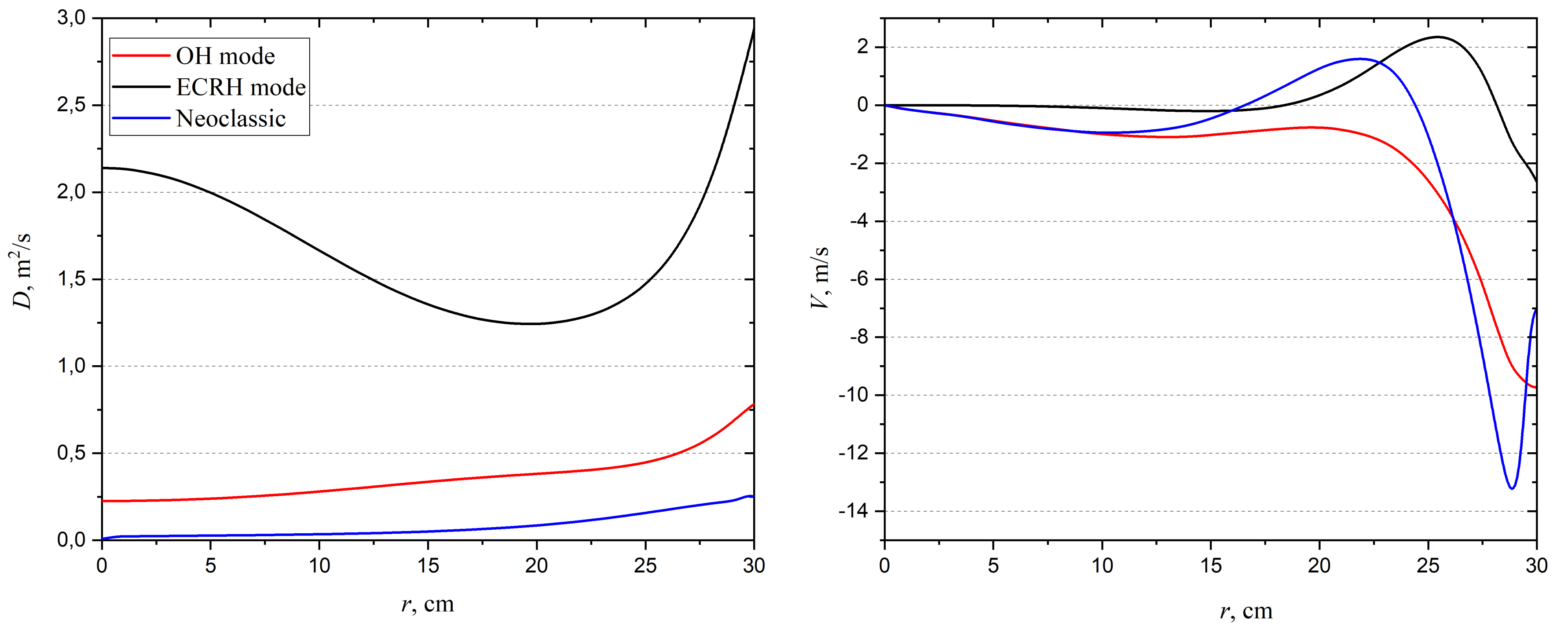

FIG. 4. Transport coefficients in discharge 70358

CONCLUSION

- The method to estimate the transport coefficients for the T-10 plasma in the ECR mode is presented. The dynamics of W removal from the central region of the column is simulated for time intervals in which the exponential decay of AXUV-signals occurs without changes in n_e and T_e. The results show that during the ECR-heating the diffusion rises by the 1.5 – 2 m2/s over the ohmic level. The pinch term shows no visible changes in the r = 0…a/2 region.
- To conduct the complete study, the selection of discharges with different ECR heating parameters suitable for processing is carried out. The Python programs to setup ASTRA model, call it and process the calculation results is coded.

ACKNOWLEDGEMENTS

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