COMPARISON OF PARTICLE TRANSPORT FOR TARGET GAS AND IMPURITIES IN ASDEX UNDER SATURATED AND IMPROVED OHMIC CONFINEMENT

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INTRODUCTION: Particle transport in ASDEX was investigated for Ohmic deuterium plasmas under saturated (SOC) and improved (IOC) confinement conditions. Transport in the target plasma was analyzed, using oscillating gas-puff experiments. The results are compared to transport of impurities evaluated from impurity gas-puffing and laser blow-off experiments under similar plasma parameters.

METHOD FOR THE TARGET PLASMA: The determination of particle transport coefficients is based on the solution of the particle conservation equation

$$\partial n/\partial t = -\nabla\cdot\Gamma + P, \ \Gamma = -D\nabla n - V\,n$$

including an ionization production term P and a general particle flux Γ with both diffusion D and convection V. This equation is linearized for small sinusoidal perturbations from equilibrium, giving an equation for the perturbed density, which can be brought into a form suited to direct numerical solution. As an improvement to the previously used analytical method /1/, /2/, this allows a better description of the radial dependences of D and V, which are evaluated by fitting the calculated values for the complex perturbation amplitude to the values measured at different interferometer chords.

TRANSPORT RESULTS: Using this scheme, particle transport can be best modelled by a constant value for D in the inner plasma region and a different, normally higher value in the confinement zone. The transition between both regions takes place within 10 to 30 % of the full radius, typically starting outside the q=1 surface. A similar dependence is found for the convective inward term, where an additional linear increase with radius has to be superimposed.

Transport parameters determined this way for hydrogen plasmas allow a good description of the measured equilibrium profiles at all densities. In deuterium this holds for densities in the linear range of τ_e (LOC), but for higher values the calculated profiles are normally more peaked than the measured ones. A possible explanation could be the substantially stronger modulation of the profile shape, found in deuterium for the same relative line density perturbation. To get a good agreement with the measured equilibrium profile for these cases, the central inward convection has to

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be fixed at a low value, while the other transport parameters are evaluated by the fitting procedure. The central diffusion and the edge values of D and V are only slightly altered by this modification, which has been used for deuterium, at the expense of a somewhat lower fitting accuracy with respect to the measured perturbation amplitudes.

In Figs. 1 and 2 the changes of the central and edge diffusion, respectively, are shown versus density. Both quantities decrease by approximately an order of magnitude between the lower and higher end of the LOC. In the SOC, D(0) and D_e remain constant, a further decrease, however, is obtained if IOC conditions are reached. In Fig. 3 the radial dependences of all transport parameters are shown for a case of beginning SOC and an IOC case. The absolute values for inward convection are nearly equal for both regimes, only the transition from low central to higher edge V seems to be shifted to larger radii in IOC. The main changes occur in the diffusive transport, which is reduced by about a factor of 3 in the outer part of the plasma for IOC and, to a less extent, also in the central region. The corresponding increase of V/D is in accordance with the steeper density gradients measured for the peaked IOC profiles /3/.

METHOD FOR THE IMPURITIES: The transport coefficients of the impurities were determined by means of sinusoidal modulated gas-puffing of SiH_4 and H_2S and, for metallic impurities like Al, Ti and Cr, using the laser ablation method. With gas puffing, the phase shift to the gas valve and the amplitude of spectroscopic signals are measured. Values for the diffusion coefficient are determined by analyzing the phase shift at a given modulation frequency and alternatively from amplitude ratios for different frequencies. Additional information about the convection velocity can be obtained by analyzing the radial profile of the fourier amplitude. The profiles of phase shift and amplitude are measured by radial scan of a spectrometer in a series of equivalent shots.

With laser ablation the characteristic times for maximum emission and exponential decay are evaluated. The transport coefficients are determined using an analytical model for anomalous transport and, for more sophisticated transport models, using an impurity transport code.

TRANSPORT RESULTS FOR IMPURITIES: For the comparison of SOC and IOC regime only the laser ablation was used so far. In first studies the transport parameters for the target plasma were inserted in the impurity transport code, but no satisfactory agreement of predicted and measured decay times could be derived. A better fit to experimental results was obtained by using the ansatz for anomalous impurity fluxes $\Gamma_Z = - D\ \partial n_Z/\partial r + V\ n_Z$ with D = const. and $V = V_a\ r/a$. We found $D \simeq 0.69\ m^2/s$ in the SOC regime and a strongly reduced value of $D \simeq 0.33\ m^2/s$ in the IOC regime. The inward drift velocity was found to be nearly the same for both SOC and IOC with $V_a \simeq 0.25$ m/s.

Figure 4 shows these parameters as a function of radius. Figure 5 shows the measured and predicted time development of the Ti XX signal for SOC and IOC regime.

In a further study we used a model with neoclassical transport and an additional anomalous diffusion term. In this case we found slightly higher values for diffusion correspdonding to the stronger neoclassical inward drift. With the model of pure anomalous transport we obtained, however, a better agreement of predicted and measured time development of signals.

CONCLUSION: A comparison of the transport parameters for electrons and impurities leads to the result that the diffusion of the impurities is substantially higher in the SOC as well as in the IOC regime. The radial dependences of D and V, however, are similar and the ratio V/D shows the same behaviour for electrons and impurities, where we see an increase at the transition from SOC to IOC regime for both species.

References:

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/2/ O. Gehre, K.W. Gentle, et al., Proc. of the 15th European Conference on Contr. Fusion and Plasma Physics, Dubrovnik (1988), Vol. 1, p. 7.
/3/ F.X. Söldner, E.R. Müller, et al., Phys. Rev. Lett, Vol. 61, No. 9, 1105.

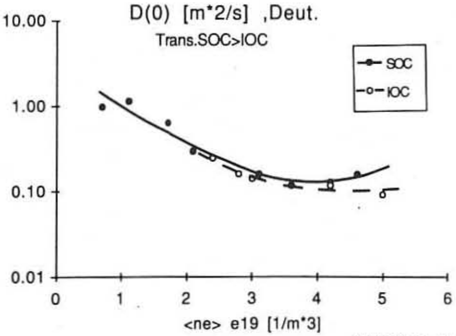

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Fig. 1: Behaviour of the central diffusion, when the average density is increased through the linear range to SOC respect. IOC values. (The open circles mark the series, where, due to wall conditions, the transition SOC → IOC was possible).

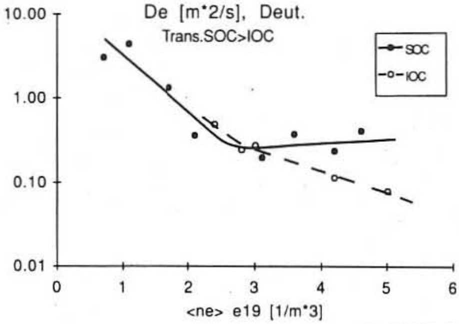

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Fig. 2: Behaviour of the edge diffusion, shown for the same series of discharges as in Fig. 1.

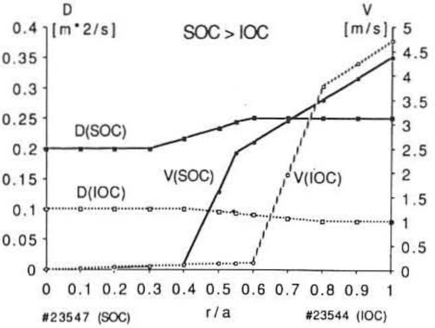

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Fig. 3: Diffusion D and inward drift velocity V in deuterium versus normalized plasma radius, shown for a SOC and an IOC case within a series.

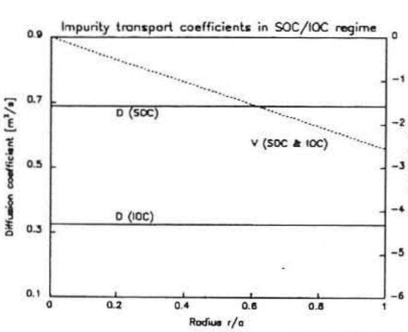

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Fig. 4: Impurity transport coefficients as a function of radius.

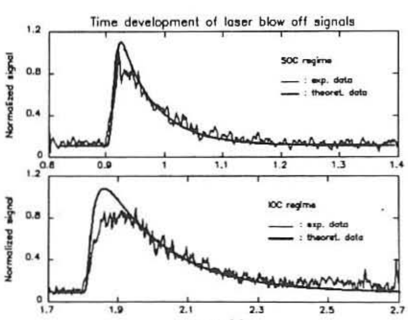

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Fig. 5: Time development of measured and predicted TiXX signal for the SOC and IOC regime, respectively. In the SOC shot #23608 laser blow off was performed at t=0.9s, in the IOC shot #23610 at t=1.8s.