# THE PARTICLE FLUXES IN THE EDGE PLASMA DURING DISCHARGES WITH IMPROVED OHMIC CONFINEMENT IN ASDEX

H.Verbeek, W.Poschenrieder, Fu J.-K., F.X.Söldner and the ASDEX Team

Max-Planck-Institut für Plasmaphysik, EURATOM Association,
8046 Garching/München, FRG

In the recent experimental period of ASDEX a new regime of Improved Ohmic Confinement (IOC) was discovered /1,2/. So far the energy confinement time $\tau_E$ increased linearly with increasing line averaged density $\bar{n}_e$ up to $n_e = 3\cdot10^{13}$ cm$^{-3}$ saturated, however, at higher densities. In the new IOC regime $\tau_E$ increases further with increasing $\bar{n}_e$ up to $\sim 5\cdot10^{13}$ cm$^{-3}$. The IOC regime is achieved for $D_2$ discharges only since the last modification of the ASDEX divertor which substantially increased the recycling from the divertor through the divertor slits. It also led to a reduction in gas consumption for a discharge by a factor of about 2. As it appears, the high fuelling rate required during a fast ramp-up of the plasma density leads to a transition into the Saturated Ohmic Confinement (SOC) regime. Vice versa, the strong reduction in the external gas feed when the preprogrammed density plateau is reached seems to be essential for establishing the IOC. It is characterized by a pronounced peaking of the density profile.

During the transition from the SOC to the IOC regime large variations in the signals of all edge and divertor related diagnostics are observed. In this paper we concentrate on the results of the Low Energy Neutral Particle Analyser (LENA), the sniffer probe, on the mass spectrometers measuring the divertor exhaust pressure.

The LENA based on a time-of-flight technique measures the charge exchanged neutral particle flux in the energy range of 30 eV to 2.8 keV. This flux is dominated by low energy particles which orginate from the areas close to the plasma edge /3,4/. The neutral particle flux observed in these measurements is to a large extent produced by the plasma recycling at the tip of the large graphite limiter positioned at the outward edge of the SOL in close proximity to the LENA. The neutral particle flux $\Phi$ scales very well with the particle content in the SOL namely with $n_S\cdot\lambda_n$ i.e. with the density at the separatrix $n_S$ times the decay length of the density outside the separatrix $\lambda_n$ as measured with the Li-beam diagnostic /5/.

In the plasma chamber 2 cm behind the protective limiter the sniffer probe is located. It measures charged particle fluxes parallel to the magnetic field in the boundary plasma. The ion fluxes can be obtained from the pressure rise in the exhaust of the probe with the response time of 120 ms. It has also an integrated Mach probe which can be biased to draw ions or electrons and yields a very fast response to flux changes. A good agreement between ion saturation current and measured H- flux has been found. It is therefore related to the recycling in the main chamber /6/.

The exhaust pressure of the upper and lower divertors of ASDEX is measured with mass spectrometers. They can be repeatedly scanned over a group of masses (normally 1 to 4) in $\sim$125 ms, thus delivering the time dependent partial pressures, or can be set to a specific mass (4 in this paper) which yields better time resolution. This divertor pressure results from the plasma flux in the scrape-off layer streaming into the divertor. The divertor pressure in turn is the direct measure for the neutral gas recycling into the main chamber via the bypasses /7/.

In each of figs. 1 and 2 a shot with substantially improved confinement and another one with little improvement are compared.

In fig. 1 shot # 23351 with clean steel walls shows the IOC regime, while in shot # 23862 with carbonized walls only a modest improvement of the confinement occurs in this otherwise equal discharge. For both shots $\overline{n}_e$ was ramped up to a flat top at $\overline{n}_e = 4.5 \cdot 10^{13}$ cm$^{-3}$ by the controlled gas valve. GASV shows the voltage at this piezo valve, while $Q_{GAS}$ is the total amount of gas used to maintain this discharge. The changes in the confinement time $\tau_E$ are shown in the last row. While $\overline{n}_e$ is ramped up at 0.7 sec $\tau_E$ rolls over and even decreases somewhat in the SOC regime. At 1.2 sec $\tau_E$ increases again with the beginning of the IOC regime. This increase is much less in the case of carbonized walls (# 23862). In the third row the neutral particle flux $\phi$ is shown. It increases as $\overline{n}_e$ increases. With the onset of the IOC regime $\phi$ decreases rapidly. The signal of the sniffer probe $I_{SN}$ behaves quite similar. In this case the Mach probe was biased positively; it measures therefore the plasma electron flux. The close relation of the neutral particle flux $\phi$ and the plasma flux in the region outside the SOL shows that $\phi$ is dominated by the recycling at the protection limiter located in close proximity. With some delay, owing to the vacuum time constants involved, also the divertor pressure decreases after the onset of the IOC. In the case of carbonized walls, where only a poor improvement of $\tau_E$ occurs only a modest reduction of $\phi$ and the divertor pressure is seen. $I_{SN}$ behaves accordingly.

The strong reduction in recycling fluxes shown by the neutral flux $\phi$, the divertor pressure, and the sniffer probe signals mark an improvement in the particle confinement. Obviously the reduction in $\tau_E$ is the consequence of this improved particle confinement.

Figure 1 shows that an alteration of the walls - carbonisation hereby - has a large impact on the plasma edge. In the case of carbonization, after the ramp-up of $\overline{n}_e$, the divertor pressure, the neutral flux, and the plasma flux in the boundary (sniffer probe) reach much higher values. The gas consumption $Q_{GAS}$ shows an opposing behavior: The $Q_{GAS}$ is high during the ramp-up and low in the good IOC regime achieved with steel walls and, conversely, is first low and then high in the $\overline{n}_e$-plateau with carbonized walls.

It should be mentioned that the ratio of the pressure in the upper and lower divertors (not shown in fig. 1) has a minimum where the maximum of the edge diagnostics discussed here (at 1.2 sec) occurs. This indicates a change of the anomalous transport which is partly responsible for this divertor asymmetry.

In fig. 2 two discharges with a slightly different toroidal field $B_T$ and thus $q_a$ but otherwise equal parameters are compared. The density was ramped up to 3 plateaus with $\overline{n}_e = 2.6$, 4.0, and $4.6 \cdot 10^{13}$ cm$^{-3}$. The neutral flux, the divertor pressure, and the gas consumption indicate that the IOC regime is reached in the second and third density plateaus for $q_a = 2.77$. This is much less pronounced in the discharge with $q_a = 3.01$. Again, all the edge particle flux measurements consistently show the same tendency. This demonstrates once more the critical dependence of the IOC regime on the plasma edge conditions, since the decay length $\lambda_n$ in the SOL scales proportional with $q_a$.

Though it was hoped for, that a more detailed study of the plasma-edge fluxes and recycling might reveal some more clues to the chain of causality responsible for loss and reestablishment of the regime with linear increase of confinement, the question of the actual trigger remain still unresolved. The fuelling rate from the feed-back controlled gas valve appears here to be an important parameter. An analysis of many shots shows that IOC conditions are only reached if this rate is above 20 mbar l/s during ramp-up. If it stays below, as is typical for carbonized walls, only SOC has been observed.

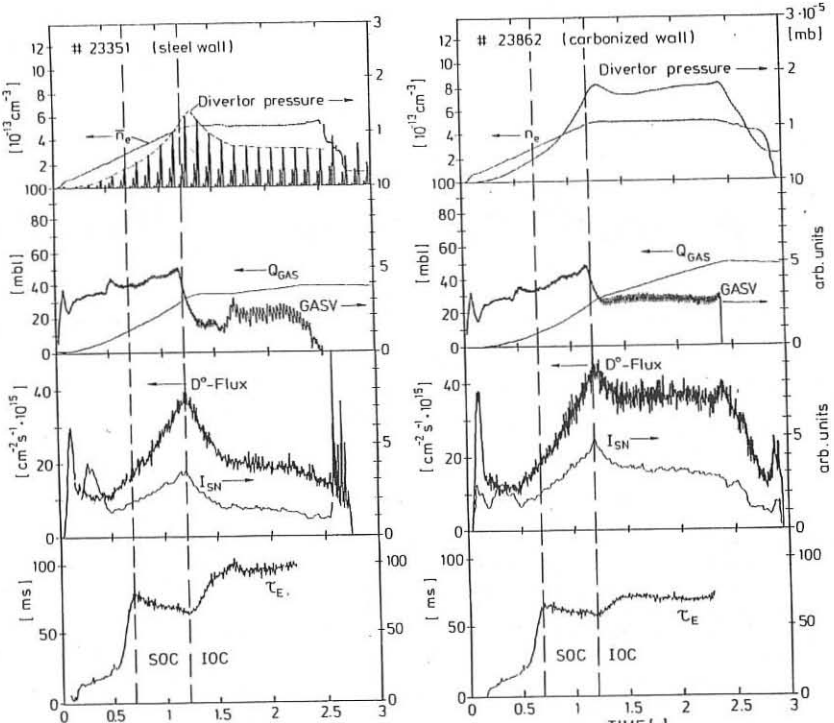

Fig. 1: Time evolution of the line averaged density $\bar{n}_e$, the pressure in the lower divertor, the voltage at the controlled gas valve GASV, the consumed gas $Q_{GAS}$, the neutral flux, the electron current from the sniffer probe $I_{SN}$, and the energy confinement time $\tau_E$ for $D_2$-discharges with steel walls (left) and carbonized walls (right) but otherwise equal parameters.

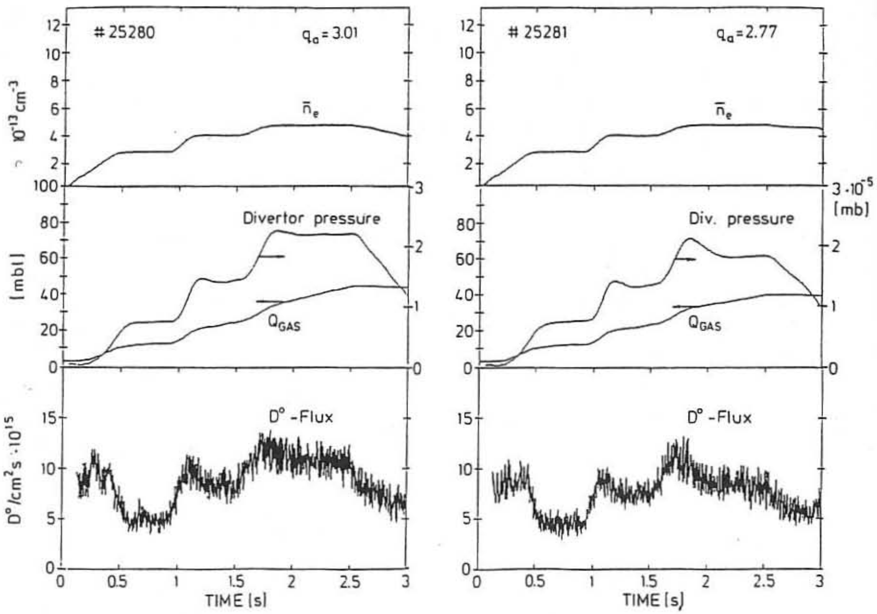

Fig. 2: Time evolution of the time averaged density $\bar{n}_e$, the divertor pressure, the consumed amount of gas $Q_{GAS}$, and the neutral particle flux $D_2$-discharges with $q_a = 3.01$ ($B_T = 2.36$ T) (left) and $q_a = 2.77$ ($B_T = 2.17$ T) (right) but otherwise equal parameters.

References:
/1/ E.R.Müller et al., Europhysics Conf. Abstr. 12B (1988) 19
/2/ F.X.Söldner et al., Phys. Rev. Lett. 61 (1988) 1105
/3/ H.Verbeek, J. Nucl. Mat. 145-147 (1987) 523
/4/ H.Verbeek et al., Proc. 8th PSI-Conf., Jülich 1988
/5/ K.McCormick et al., this conference
/6/ W.Poschenrieder et al., Europhys. Conf. Abstr. 9F (1985) 587
/7/ G.Haas, W.Poschenrieder et al., Proc. 8th PSI Conf. Jülich 1988