MOMENTUM CONFINEMENT STUDIES ON ASDEX

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1. Introduction

The toroidal plasma rotation induced by unbalanced neutral beam injection is a measure of plasma confinement, especially ion confinement. Since rotation velocities are experimentally easier accessible than ion temperatures, and the physics of momentum transport permits the neglection of electron transport effects, the study of momentum confinement is an effective diagnostic tool. We have investigated the rotational behaviour of the ASDEX plasma under different neutral beam heating schemes using charge exchange recombination (CXR) spectroscopy on up to five lines of sight [1]. Comparing the momentum confinement times derived from rotational profiles with the corresponding energy confinement times derived from β_{pol} measurements, the main differences and common features of momentum and energy confinement are discussed.

2. Experimental procedure

The plasma bulk rotation was determined from the Doppler shift of the CXR-excited C^{5+} (343.4 nm) line after subtraction of a cold, edge excited blending feature from the measured line profile. Five lines of sight in the outer plasma midplane have been used simultaneously, which intersect the northwest neutral beam line at r/a= 0.125, 0.375, 0.625, 0.875 and 1. In order to reduce the number of data points and to obtain a comparative figure, global momentum confinement times were deduced by integrating the momentum of the particles with respect to the whole plasma volume. To facilitate this, an exponential fit has been applied to each radial rotation (half-) profile which was extended to the inner part of the plasma under the assumption of constant angular rotation frequency of a flux surface [2]. For steady state conditions, the global momentum confinement time can be calculated as the quotient of plasma angular momentum, L, and beam torque, Γ: $\tau_\Phi = L/\Gamma$.

3. Results

Figure 1 shows the typical rotational behaviour of the ASDEX plasma with co and counter neutral beam injection under identical experimental conditions. Although the density rises during the counter NI, the plasma speeds up to a considerable higher velocity, which is an expression of improved confinement of momentum. Parallel to the observed improvement of momentum confinement, the energy confinement time increases as well [3].

The temporal and spatial development of the angular rotation frequency with D^0 injection under similar conditions as those of Fig. 1 are plotted in Figure 2. The corresponding rotation speed has slightly raised against that achieved with H^0 injection due to the higher torque of the deuterium beam in comparison with the hydrogen beam at the same injection power.

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In order to reduce the thermal load of the divertor plates and the erosion of copper, CD_4 is puffed into some ASDEX discharges. This measure increases considerably the duration of the counter NI discharges. As illustrated in Fig. 3, the additional CD_4 puffing slows down the rotation speed and prevents the plasma from further acceleration as observed from the counter NI discharges without methane puffing. A comparison of the temporal development of the momentum confinement times of a standard discharge, a discharge with pellet fuelling and the discharge with CD_4 puff is given in Fig. 4a, the corresponding energy confinement times are plotted in Fig. 4b. Although the two quantities scale in the same way, the change of confinement comes out much more clearly in the momentum confinement time than in the energy confinement time. It should be noted, that the steepest rise in momentum confinement without CD_4 puffing appears just when the sawteeth disappear in these discharges ($t \approx 1.25$ s), whereas the sawteeth do not disappear with CD_4 puffing and τ_ϕ stays at a lower level [4]. Pellet fuelling does not affect the momentum confinement drastically. While τ_ϕ is slighly improved during the pellet fuelled discharge, at its end this improvement stops. At the same time, the energy confinement begins to degrade until a disruption occurs.

Another example for the sensitivity of momentum confinement against changes of discharge parameters is given in Fig. 5. Here, at $t=1.0$ s, the number of active beamlines has been reduced from 3 to 1 and, additionally, CD_4 puffing has been reduced. As a result, τ_E increases moderately, but τ_ϕ is drastically improved, in contrast to the normally observed independence of τ_ϕ from the applied torque. The discharge is able to maintain the high angular momentum even with one third of the primary input torque over many of the (old) momentum confinement times.

The opposite behaviour is obtained, when additional ICRF heating is applied to the plasma with counter NI. As to be seen in Fig. 6, with ICRH the usually strong improvement of momentum confinement with counter injection fails to appear and τ_ϕ remains at a comparatively low level in the vicinity of τ_E. An interesting feature appears near the end of the discharge: A minor disruption causes the plasma to lose a part of its mass and the energy confinement time is pushed near zero. But while τ_E recovers in part after the event, the rotation of the plasma does not reappear although the torque of the neutral beams is still applied. In fact, such exceptional situations are the only occasions where momentum confinement times significantly smaller than the corresponding energy confinement times were found in ASDEX, in contrast to the results obtained with limiter machines, where τ_ϕ has typically half the value of τ_E [5].

4. Conclusion

The global momentum confinement time derived from rotational profiles of the plasma has been found to be a sensitive detector for changes in plasma confinement, with variations arising in the energy confinement time generally coming out more pronounced. A number of features in the rotational behaviour have been found, which still have to be explained: The strong increase of τ_ϕ during ctr.-NI, its degradation by ICRH and the strong influence of CD_4 puffing on the confinement of momentum. Since at the moment no theory of plasma viscosity exists which is able to describe the transport of momentum in detail, a simple analysis in terms of momentum diffusion seems to be appropriate. Comparing the momentum confinement behaviour with that of the energy or particle confinement times, new insight may be gained concerning the overall plasma development.

References

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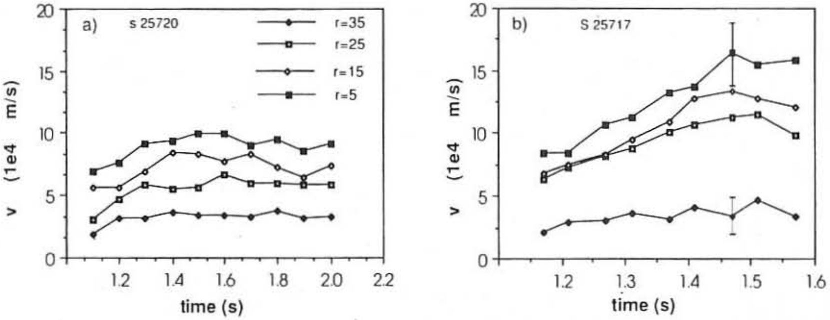


Fig. 1 Rotational behaviour with co and ctr. $H^0 \to D^+$ injection.
a) co injection.

b) counter injection.

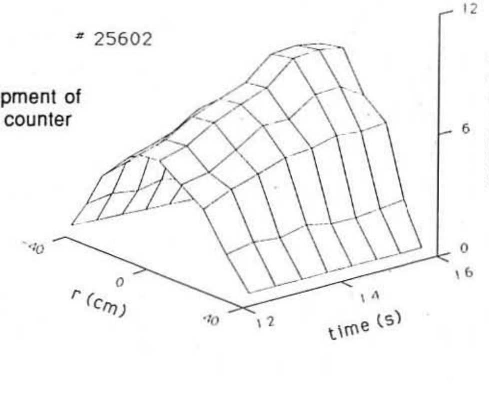
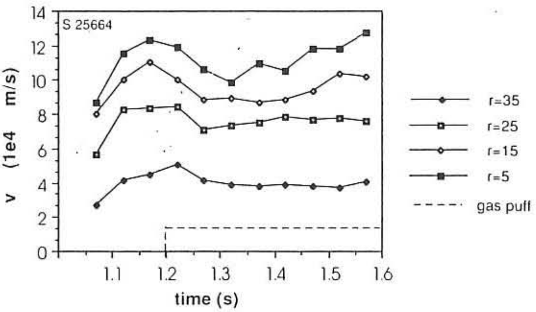


Fig. 2 Temporal and spatial development of the angular rotation frequency with counter injection, $D^0 \to D^+$.

Fig. 3 Temporal development of the rotation at different plasma radii when CD_4 is puffed into the ctr-NI discharge.



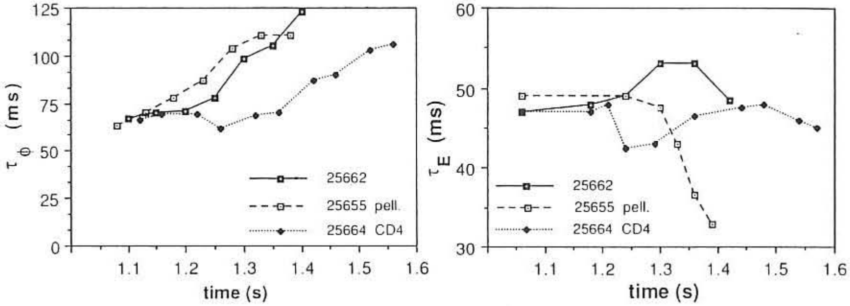


Fig. 4 **a)** Comparison of counter injection momentum confinement times with standard fuelling, pellet fuelling and additional CD_4 puffing. **b)** corresponding energy confinement times.

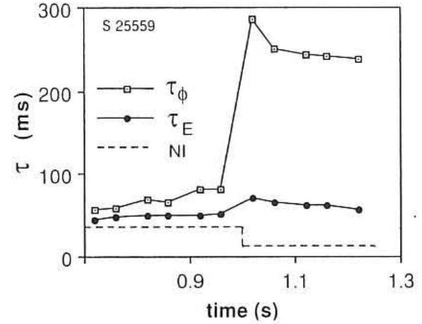


Fig. 5 Improvement of momentum confinement by the reduction of ctr.-NI and CD_4 puffing.

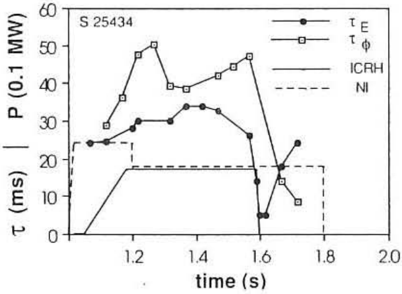


Fig. 6 Momentum confinement with ICRH and counter injection D^0->D^+.