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Effects of active divertor cryo-pumping on particle exhaust in Wendelstein 7-X

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In the recent experimental campaign OP2.2, the neutral gas pressures previously measured in the subdivertor of Wendelstein 7-X could be confirmed and improved with subdivertor neutral gas pressures of $3{\cdot}10^{-3}$\,mbar routinely reached in standard as well as high iota configuration. Those two magnetic field configurations differ by the number and positions of the edge magnetic islands and their areas of intersection with the divertor targets, leading to strike lines on different parts of the divertor and thus different distributions of neutral gas pressure in the subdivertor volume. In standard configuration, effective particle confinement times of 5-10\,s were determined regardless of the state of the cryo-vacuum pumps. Due to higher neutral gas pressures at otherwise similar plasma parameters, lower effective particle confinement times could be reached in the high iota configuration, leading to better particle exhaust. Additionally, a significant effect of cryo-vacuum pumping on the effective particle confinement times could be determined with the mean effective particle confinement time decreasing by more than half from 8.7\,s during discharges without cryo-vacuum pumping to 4.0\,s during discharges with cryo-vacuum pumping. Similarly, the recycling coefficient in standard configuration was determined to be on average 0.97 and remains unaffected by cryo-vacuum pumping, whereas the mean recycling coefficient of 0.98 reached in high iota configuration without cryo-vacuum pumping is reduced to 0.95 when the cryo-vacuum pumps are used. \\
%Additionally, density control during discharges using only cryo-vacuum pumping has been demonstrated for long %plasma discharges with steady-state pellet injection.\\
DSMC (Direct Simulation Monte Carlo) simulations of the neutral gas pressure in the subdivertor volume using the DIVGAS computational platform confirm the decrease of the neutral gas pressure by up to 11% when using the cryo-vacuum pumps and thus confirm the improved particle exhaust realized by cryo-vacuum pumping in the high iota configuration [2].

[1] O Grulke et al. "Overview of the first Wendelstein 7-X long pulse campaign with fully water-cooled plasma facing components". In: Nucl. Fusion 64.11 (2024), p. 112002.
[2] S Varoutis et al. "Numerical analysis of gas exhaust in Wendelstein 7-X using the Direct Simulation Monte Carlo method". In: Nuclear Fusion (2025).

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