Status of impurity transport in W7-X with focus on the plasma boundary results and the reactor perspective

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Impurity transport and dynamics in the boundary and the conf ned region of a stellarator are crucial aspects of stellarator operation both regarding plasma performance and the power exhaust physics. The retention of impurities in the Scrape-Of Layer and divertor sets the balance between available radiation losses for power exhaust and the core impurity level. The latter determines operationally accessible plasma parameters via the density limit [1]. Impurity transport in the conf ned plasma also was a limiting factor in devices like W7-AS [2] and LHD [3] via impurity accumulation due to unfavorable neoclassical transport in stellarators. Given an allowable core content of impurities in a reactor, the core impurity transport and the divertor enrichment parameter determine the limit of the amount of divertor impurities that can be used for power dissipation [4]. It also def nes the required particle exhaust rates to provide suf cient particle throughput for impurity control, particularly important with respect to He-ash removal in a later reactor. Characterizing the impurity dynamics in W7-X is therefore curcial to assess the applicability of the island divertor (ID) concept for a future reactor concept. In the OP1.2b campaign of W7-X, we have found that the impurity transport is widely turbulence dominated and consequently is correlated with parameters such as gradient scale lengths or T_e/T_i [5,6,7,8]. In specif c turbulence-suppressed scenarios the impurity transport is locally consistent with the neoclassical predictions [7] and ECRH is observed to control the level of impurity accumulation in these conditions [9]. To accurately measure core transport inside $r/a < 0.4$ additional diagnostic data (XMCTS) was included into the modeling framework pySTRAHL [10]. The implementation of new diagnostic approaches and installations, such as source modulation techniques or the new laser blow of manipulator, will be crucial for the upcoming campaign. Edge impurity transport studies showed proof of good retention in the island divertor for intrinsic carbon and seeded nitrogen [11,12]. New concentration measurement techniques are being validated [12,13]. EMC3-Eirene modeling implies a potential paradigm shift in the transport picture of island divertors. In the usually observed friction force dominated parallel transport regimes [14] of W7-X, the simulations predict a dominant role of the perpendicular transport across the island O-point along the 'upstream' f ow stagnation zone [15]. This leads to a variation of the impurity retention based on the source location, which will now be tested in the upcoming campaign of W7-X.

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