

# Impurity Transport in Ion- and Electron-Root Plasmas of Wendelstein 7-X

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In non axis-symmetric, magnetic confinement fusion devices like the optimized stellarator Wendelstein 7-W (W7-X), recent theoretically predicted aspects on impurity transport, as the existence of a mixed collisionality regime<sup>1</sup> or the build up of a radial electric field  $E_r$ <sup>2</sup>, have been addressed in several initial experimental studies. Based on measurements of impurity transport times<sup>3,4</sup> or radial impurity diffusivity profiles<sup>5,6</sup>, these studies are hinting for a strong anomalous impurity transport mechanism in W7-X.

In this work, a possible suppression of the anomalous impurity transport in a so-called ion-root plasma scenario is investigated, as in those scenarios already a significant improve of the energy confinement has been observed<sup>7</sup>. Using X-ray imaging spectrometer (XICS) data, impurity density profiles of neighboring Ar charge states, namely  $n_{Ar^{15+}}$ ,  $n_{Ar^{16+}}$ , and  $n_{Ar^{17+}}$  (see Fig.1), are used to derive impurity fluxes of  $Ar^{16+}$  as described in detail elsewhere<sup>5</sup>.

In Fig.2, experimentally derived, radial fluxes of  $Ar^{16+}$  are shown comparatively for an experiment program during a pure ion-root confinement time interval (Fig.3 a) and a central electron root confinement (CERC) phase (Fig.3 b).

As evident from Fig.2, in the CERC scenario a positive, radially outwards directed Ar flux from the plasma center up to half of the plasma radius  $\rho = 0-0.5$  (see dashed line) is observed, being dominant over a negative, radially inwards directed Ar flux from half of the plasma radius to the plasma edge. In the ion-root scenario, this positive Ar flux is restricted to the plasma center, now with a dominant negative radially inward directed Ar flux in the entire bulk plasma region of  $\rho > 0.2$ .

Finally, Fig.3 c)+d) show measured diffusion and velocity profiles, derived from the above shown Ar flux measurements for the ion-root plasma scenario. Compared to typical diffusivities of  $D \sim 1.5-3 \text{ m}^2/\text{s}$  measured in CERC plasmas (see shaded area in Fig.3c)<sup>5,6</sup>, one finds a significantly reduced impurity diffusivity  $D$  in the plasma bulk region  $\rho = 0-0.6$ , accompanied by a strong negative convection velocity  $v$  for the ion-root confinement scenario.

As the ion- and electron-root plasma scenarios exist at different values of  $n_e$ ,  $T_e$ , and  $T_i$ , additional neoclassical STRAHL simulations are performed to disentangle possible  $n_e$ ,  $T_e$ , and  $T_i$  contributions to the observed changes in the Ar fluxes, by comparing STRAHL simulated and measured Ar density profiles, given the measured diffusion and velocity profiles.

## References:

- <sup>1</sup> P. Helander, S.L. Newton, A. Mollén et al. Phys. Rev. Lett. 118, 155002 (2017)
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- <sup>3</sup> A. Langenberg, F. Warmer, G. Fuchert et al. Plasma Physics and Controlled Fusion 61, 014030 (2019)
- <sup>4</sup> Th. Wegner, B. Geiger, F. Kunkel et al. Review of Scientific Instruments 89 073505 (2018)
- <sup>5</sup> A. Langenberg, N.A. Pablant, O. Marchuk et al. Nuclear Fusion 57 086013 (2017)
- <sup>6</sup> B. Geiger, Th. Wegner, C.D. Beidler et al. Nuclear Fusion 59 046009 (2019)
- <sup>7</sup> R. Wolf, A. Alonso, S. Akkäslompolo et al. Physics of Plasmas 26 082504 (2019)

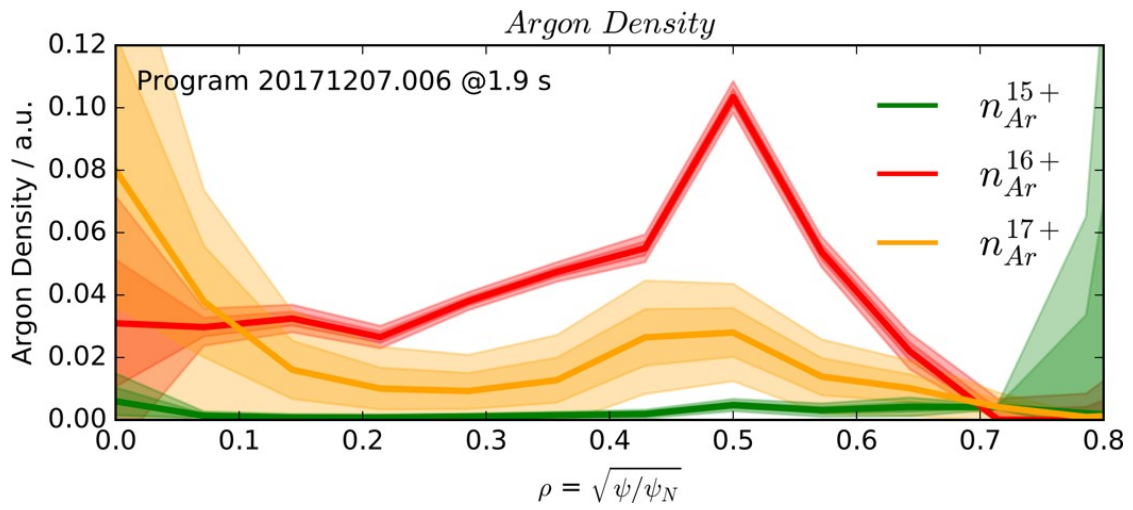


Figure 1: Argon XVI - XVIII impurity density profiles as measured by XICS in a W7-X ion-root plasma scenario.

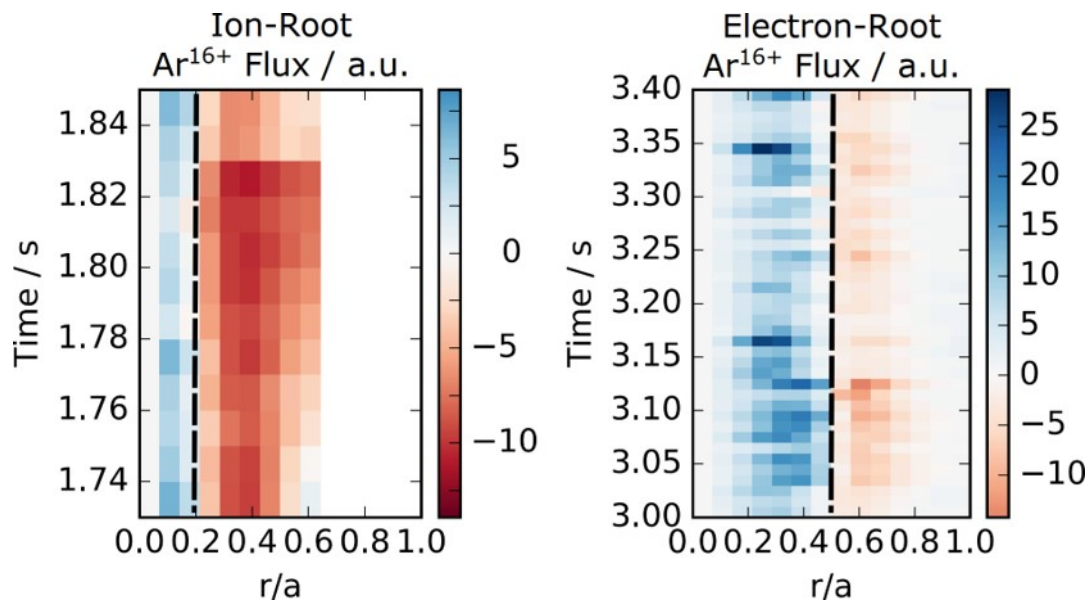


Figure 2: Experimentally derived Ar<sup>16+</sup> fluxes for an ion-root and a central electron-root plasma scenario. Positive fluxes (radially outward directed) are shown in blue, negative fluxes (radially inward directed) are shown in red.

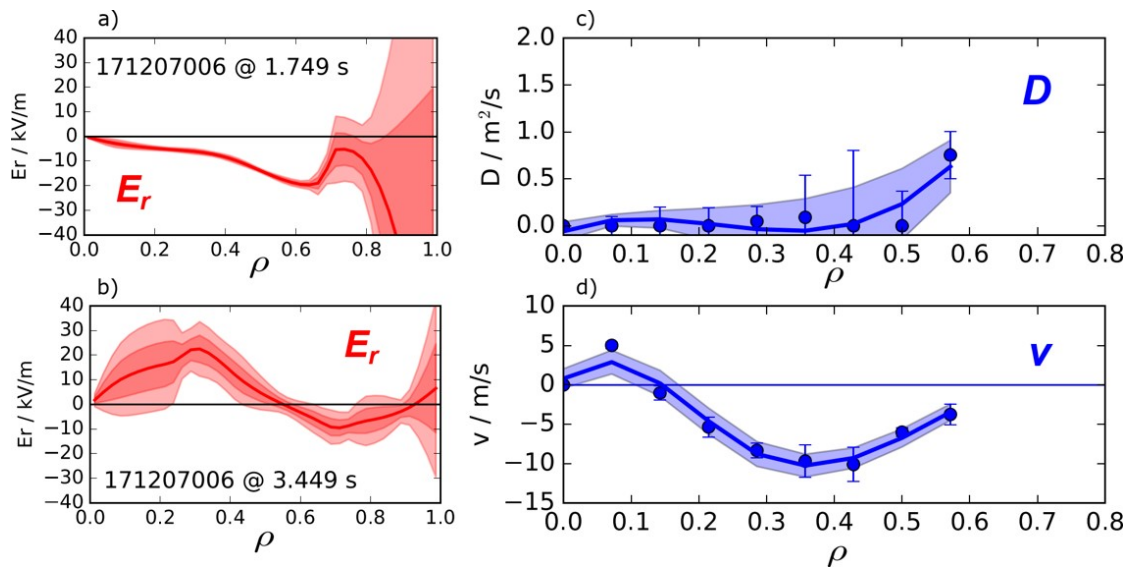


Figure 3: a)+b) Experimentally observed radial electric fields for a) ion- and b) electron-root confinement. c)+d) Ar diffusion and convection profiles in an ion-root plasma scenario. Shaded area denotes typical observed maximum D values in CERC plasma scenario.

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