Transport phenomena in the SOL of ASDEX Upgrade

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Abstract: A probe head, combining electrostatic and magnetic probes, was used on the midplane manipulator and inserted into the scrape-off layer (SOL) of ASDEX Upgrade (AUG). The electric signals of six probe tips allow the determination of turbulent radial particle fluxes, Reynolds stress and transport of poloidal momentum. Here special emphasis is laid on the momentum flux, revealing the fine structure of single ELM filaments. Magnetic signals were analyzed in order to recognize the occurrence of possible current filaments associated to type I ELMs. From the components of the magnetic field perturbations we obtain hodograms, which are direct indications of ELM current filaments aligned with the ambient magnetic. The results are compatible with the existence of toroidal current filaments as predicted by various ELM theories.

Probe head for simultaneous registration of electric and magnetic signals in the SOL of AUG:

Electric signals – radial transport of poloidal momentum during ELMs

This probe arrangement allows the determination of poloidal and radial electric field and plasma density (d_e – 5 mm in poloidal direction, d_r – 3 mm in radial direction):

\[
E_{r} = \frac{\Delta V}{\Delta d_r} \quad \text{and} \quad E_{\phi} = \frac{\Delta V}{\Delta d_{\phi}}
\]

Of course, here we have to assume that the electron temperature is the same on all probe plate positions! (It could be better to use different elevation heights but is not yet possible.)

From these results, the radial particle transport \(J_r\), the radial stress \(\nu_r\), and the radial transport of poloidal momentum \(M_r\), can be derived:

\[
J_r = \frac{1}{d_r} \int E_{\phi} \, d_t \quad \text{and} \quad \nu_r = \frac{1}{d_r} \int \left( \frac{d E_{\phi}}{d t} - \frac{\partial E_{\phi}}{\partial r} \right) \, d_t \quad \text{and} \quad M_r = \frac{1}{d_r} \int \left( \frac{d}{d t} \int E_{\phi} \, d_t \right) \, d_r
\]

With \(d_{\phi} = d_t \int E_{\phi} \, d_r\), the momentum flux splits up into four contributions:

\[
M_r = \frac{1}{d_r} \int \left( \frac{d}{d t} \int E_{\phi} \, d_r \right) \, d_t
\]

The first term of \(d_{\phi}\) contains the Reynolds stress and the second one is the convective transport of poloidal momentum. The third term is the triple-product transport of poloidal momentum and does not contribute on average, because if \(\nu_r \approx 0\), \(M_r\) does not contribute on average, because if \(\nu_r \approx 0\).

Magnetic signals – ELM current filaments

Conclusion: Assuming a monopolar filament flowing with velocity \(u_{\phi}\), the current can be estimated noting that:

\[
\frac{d r_{\phi}}{d t} = \frac{u_{\phi}}{v_{\phi}} \quad \text{and} \quad \frac{d r_{\phi}}{d t} = \frac{u_{\phi}}{v_{\phi}}
\]

Consequently

\[
\frac{d r_{\phi}}{d t} = \frac{u_{\phi}}{v_{\phi}}
\]

Based on these assumptions we obtain a current \(I_L\) = 1.7 kA. With 1 cm radius of the filament this corresponds to a current density up to 6 MA/m².