Gyrokinetic modelling of stationary electron and impurity profiles in tokamaks

A. Skyman¹, D. Tegnered¹, H. Nordman¹, P. Strand¹

¹ Department of Earth and Space Sciences, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

In order to optimize the performance of fusion devices the main ion profiles need to be peaked, since it enhances the fusion power production, while the impurity profiles should be hollow in order to minimize fuel dilution and radiation losses. Peaked profiles, in the absence of particle sources in the core, are a result of an inward pinch caused by turbulent transport. Stationary profiles are obtained from a balance of diffusion and convection resulting in zero particle flux.

Particle transport due to Ion Temperature Gradient (ITG) and Trapped Electron (TE) mode turbulence is studied using the gyrokinetic code GENE. Reduced quasilinear (QL) and nonlinear (NL) simulations are performed for parameters taken from the Cyclone Base Case, an ITG dominated scenario.

Since the electron density gradient can greatly affect the stationary impurity profile scaling a self-consistent treatment is used whereby the stationary local profiles corresponding to zero particle flux are calculated simultaneously for both electrons and trace impurities, as opposed to using a prescribed electron density gradient which is often done in similar studies of impurity peaking. Impurities with a charge in the region $3 \leq Z \leq 42$ are included in low concentrations as trace species.

The scaling of these profiles with regards to magnetic shear, safety factor, electron-to-ion temperature ratio, collisionality, toroidal sheared rotation, triangularity and elongation is discussed for a deuterium (D) plasma. Out of these parameters, the stationary background density profile is shown to be sensitive to scans over magnetic shear, collisionality, elongation and temperature ratio, for which simultaneous zero flux impurity profiles are calculated. This treatment yields mainly enhanced parameter scaling of the impurity profile peaking. For most considered cases both electron- and impurity profiles were found to be inwardly peaked with a stronger peaking for the electrons.

The isotope scaling for hydrogen (H) and tritium (T) plasmas are also studied. A slight asymmetry between hydrogen, deuterium and tritium with respect to profile peaking is found for scans in collisionality and temperature ratio, in particular.