Neutral particle analysis of NBI heated plasmas in the ST40 spherical tokamak

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ST40 is a high-field, low-aspect-ratio spherical tokamak with a major radius of 0.4 m, aspect ratio of 1.8 and toroidal magnetic field of 3 T. One of the goals of the device is to demonstrate fusion relevant conditions, including high ion temperatures, in a spherical device. For this purpose, it is equipped with a 15-channel neutral particle analyser (NPA), which can be used to infer the main ion temperature within the plasma. Additionally, with up to 2 MW of NBI power in the compact ST40 plasmas, a significant fraction of the pressure and stored energy is contributed by the fast ions. When coupled with modelling and synthetic diagnostics, the NPA provides the capability to analyse the distribution and time evolution of the fast ions in detail.

A fast line-integrated, semi-analytic synthetic diagnostic has been implemented to estimate the main ion temperature by fitting a Maxwellian distribution to the measured neutral fluxes. The model can account for realistic temperature and density profiles along the line of sight and can be run intershot between pulses. For fast particle fluxes due to the NBI ions, the Monte Carlo orbit-following code ASCOT5 has been coupled with the synthetic NPA module of FIDASIM. The fast ion slowing-down is simulated with ASCOT, and the resulting neutral fluxes are calculated with realistic geometry and time-dependent 4D distribution functions.

During ohmic heating phases, the ion temperature is routinely determined using the semi-analytic model, and good fits are obtained for the signal in the 1 - 5 keV channels. During NBI injection, the signal is dominated by the slowing-down distribution of the fast ions. This complicates the analysis of the thermal signal and measurements of the ion temperature, but the distribution function can be determined with good time and energy resolution.