Real-time control of NBI fast ions, current-drive and heating properties

<u>M. Weiland</u>¹, O. Kudlacek¹, B. Sieglin¹, R. Bilato¹, W. Treutterer¹, the ASDEX Upgrade Team and the EUROfusion MST1 Team ¹Max-Planck-Institute for Plasma Physics, Garching, Germany

Traditionally, plasma heating via neutral beam injection (NBI) is controlled via engineering parameters such as injected power, injection voltage, beam geometry etc. For advanced experiments, it would be beneficial to control directly certain properties of the NBI heating, such as the amount of ion heating. For example, the ion heat flux (i.e. ion heating plus equipartition) triggers LH-transitions [1], and in transport experiments, it is useful to study different plasma scenarios (e.g. H and D plasmas [2]) with identical ion heat fluxes.

Recently, the real-time NBI code RABBIT [3] has been coupled [4] to the discharge control system of ASDEX Upgrade. This allows to calculate in real-time the NBI fast-ion distribution and all derived quantities such as ion- and electron heating, fast-ion densities and the driven current. Consequently, it becomes now possible to control these quantities, and we have demonstrated this successfully in experiments at ASDEX Upgrade. For example, a certain time trajectory of the ratio of ion to electron direct heating was pre-programmed, and the control system has achieved this by interchanging NBI with ECRH. LH-transitions are triggered when increasing this ratio at constant heating power. Controllers for the fast-ion stored energy and neutral beam current drive and were also designed and successfully tested. E.g. in the latter case, a trajectory of driven current is programmed and the control system achieves it by adjusting the NBI power. This is an important first step towards real-time controlling the q-profile. The real-time calculations by RABBIT are compared to offline calculations with RABBIT and the slower, but more complete TRANSP-NUBEAM Monte-Carlo code – showing a good agreement and proving that the quantities are controlled in a correct way.

Further experiments have been started to control the electron and ion heat fluxes, which is more challenging due to lack of real-time Ti measurements. However, this could also be very useful to study alpha-particle heating by emulating it with auxiliary power [5]. In this way, the behavior of the plasma including self-generated fusion heating, which depends non-linearly on the plasma temperature (e.g. lower temperatures causing also lower heating), could be investigated already in present-day devices.

References:

[1] F. Ryter+, NF, 2014[4] M. Weiland+, NF, submitted

[2] P.A. Schneider+, NF, 2017[5] E. Fable+, NF, submitted

[3] M. Weiland+, NF 2018