Investigations on the edge radial electric field at ASDEX Upgrade
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The performance of an H-mode fusion plasma is highly dependent on the strength of the edge transport barrier (ETB). The formation of the ETB is connected to the existence of a sheared plasma flow perpendicular to the magnetic field caused by a local electric field $E$. It is widely accepted that this $E \times B$ velocity shear is fundamental for suppressing edge turbulence and thus, aiding the formation of the ETB and leading into H-mode.

At ASDEX Upgrade (AUG), radial electric field ($E_r$) profiles are determined from charge exchange recombination spectroscopy (CXRS) measurements at a heating beam and from Doppler reflectometry (DR). Since 2011 the edge CXRS system has been equipped with a toroidal and a poloidal view of the neutral beam. This enabled the determination of $E_r$ from CXRS using the radial force balance equation for impurity ions. The measurements of different impurity species provide a consistency check of the $E_r$ profile, thus, proving the validity of the diagnostic technique as all analyses ought to arrive at the same $E_r$ profile regardless of the impurity species used. The $E_r$ profile has been derived from measurements on $\text{He}^{2+}$, $\text{B}^{4+}$, $\text{C}^{6+}$ and $\text{Ne}^{10+}$ and is found to be reproducible within the uncertainties. A further cross-check of $E_r$ will be presented by comparing CXRS with DR measurements.

CXRS on main ions, i.e. deuterium (D), are difficult to interpret due to large background emissions and the beam halo. In helium (He) plasmas main ion temperature, density and rotation can be obtained from CXRS on $\text{He}^{2+}$. From these measurements $E_r$ can be calculated. The consistency of the main ion CXRS measurements can be tested by comparing the $E_r$ profile to the profiles derived from measurements on impurities in identical He plasmas.

The $E_r$ profile has been measured in various plasma scenarios including L- and H-mode. In L-mode, $E_r$ is small in magnitude and exhibits little shear, while in the ETB of the H-mode a negative $E_r$ well and a localized minimum close to the separatrix is found, consistent with observations in other fusion devices. In type-I ELM-mitigated H-mode plasmas, obtained via externally applied magnetic perturbations (MPs) with toroidal mode number $n=2$, $E_r$ has been observed to be the same as in identical H-modes without MPs. The installation of the in-vessel saddle coil system at AUG was completed during the 2011 opening, thus enabling operation with MPs up to $n=4$. The effect of the MPs from the completed set of coils on the rotation and $E_r$ profile will be presented.

The poloidal rotation profiles of different impurity ions will be compared to conventional neoclassical predictions from codes such as NEO, NEOART, NCLASS, and to simulations with HAGIS, which includes finite orbit size effects. We compare measured poloidal rotation profiles to neoclassical simulations in order to find out when conventional neoclassical theory has to be modified for the conditions in the pedestal. Novel CXRS measurements based on a localized D gas puff at the inboard midplane enable the study of asymmetries on a flux surface. From these measurements the $E_r$ profile at the high-field side (HFS) can be determined and compared to the beam-based measurements at the low-field side (LFS).