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Measurements of LHCD current profile and efficiency for simulation validation on Alcator C-Mod

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Lower hybrid current drive (LHCD) is an effective tool to significantly modify the magnetic equilibrium by driving off-axis, non-inductive current. On Alcator C-Mod, an upgraded Motional Stark Effect (MSE) diagnostic enables the current profile to be accurately reconstructed during plasmas with strong LHCD and a hard X-ray camera measures the fast electron Bremsstrahlung profile. LHCD is applied for >4 current relaxation times, producing fully-relaxed magnetic equilibria in plasmas with non-inductive current fraction up to unity at currents up to 1.0 MA. C-Mod has developed an extensive database of LHCD performance, spanning a wide range in plasma current, launched $n_{||}$, LHCD power, T_e and plasma density. This dataset provides a unique platform for validation of LHCD current drive simulations with the plasma shape, density, field and LH frequency range envisioned for ITER and future reactors. In these conditions the measured current drive efficiencies are similar to that assumed for ITER with values up to $0.4*10^{20}$A/Wm^2 despite being in a weak single-pass absorption regime. The driven current is observed to be off-axis, broadening the current profile, raising q_0 above 1, suppressing sawteeth, decreasing/reversing the magnetic shear and sometimes destabilizing MHD modes and/or triggering internal transport barriers. Measurements indicate increased efficiency at increased temperature and plasma current but with a complicated dependence on launched $n_{||}$. The MSE-constrained reconstructions show a loss in current drive efficiency as the plasma density is increased above $<n_e>$=1.0x10^{20} m^{-3} consistent with previous observations of a precipitous drop in hard x-ray emission. Additionally, the measured driven current profile moves radially outward as the density is increased. Ray tracing simulations using GENRAY-CQL3D qualitatively reproduce these trends showing the rays make many passes through the plasma at high density and predicting a narrower current and HXR profile with than that observed in the experiment. This work is supported by USDoE awards DE-FC02-99ER54512 and DE-AC02-09CH11466.