Topic: EX-S

# Isolation of Neoclassical Toroidal Viscosity Profile Under Varied Plasma and 3D Field Conditions in Low and Medium Aspect Ratio Tokamaks*

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**Abstract:** Neoclassical Toroidal Viscosity (NTV) due to non-ambipolar particle diffusion occurs in tokamaks due to low magnitude ($\delta B/B_0 \sim O(10^{-3})$) three-dimensional (3D) applied magnetic fields, used for positive purposes including alteration of the plasma rotation profile, $\omega_\phi$, to stabilize MHD modes and for ELM suppression. As ITER and future devices will use 3D fields for these purposes, it is important to accurately quantify NTV effects over key plasma and 3D field variations. The present work quantitatively analyzes and compares a formidable combination of NTV databases from two tokamak devices of significantly different aspect ratio. These data allows testing of NTV theory over a broad range of plasma variables including aspect ratio, $q_{95}$, collisionality, gyroradius, plasma rotation speed and profile, as well as 3D field strength and spectrum. Isolation of the NTV torque profile, $T_{NTV}$, is accomplished by applying the 3D field faster than the plasma momentum diffusion time. A dedicated international experiment was run in late 2015 to measure the NTV profile this way for the first time in the KSTAR superconducting tokamak at medium aspect ratio ($A \sim 3.5$). Over 360 variations of the parameters mentioned above were produced. These results are compared to new analysis of complementary experimental results from the extensive NTV database of low $A \sim 1.3$ NSTX plasmas. The NSTX experiments yield unique information in plasmas with computed displacements smaller than the ion banana width, showing that finite-orbit effects will average $T_{NTV}$ over such spatial scales. In KSTAR, six different 3D field spectra were run, including dominantly $n = 2$, $n = 1$ field pitch-aligned, $n = 1$ field pitch non-aligned configurations, and their superposition. As expected by theory, the measured rotation profile change due to the 3D field, $\Delta\omega_\phi$, does not change sign, and is close to zero near the plasma boundary. All cases show broader $\Delta\omega_\phi$ than found in NSTX. The change to the relative pitch alignment of the applied 3D field yielded a clear and unexpected result: the non-pitch-aligned field configuration produced a stronger change to the $\omega_\phi$ profile than the pitch-aligned case. The $\Delta\omega_\phi$ is global and non-resonant, with no strong indication of localized resonant effects, similar to NSTX results in different field configurations.

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