Prompt, Collisionless Toroidal Momentum Balance with Short Neutral Beam Pulses in DIII-D*

J.S. deGrassie, K.H. Burrell, and R.J. Groebner

General Atomics, P.O. Box 85608, San Diego, California 92186-5608, USA

In H-mode discharges with neutral beam injection (NBI) pulses short compared with the fast ion scattering time it is observed that the plasma typically stores all the toroidal angular momentum delivered by the NBI torque impulse. This NBI time is also short compared with the plasma energy confinement time. Computations with TRANSP show that during the pulse approximately 90% of this torque is delivered via the collisionless fast radial current injection process,[1] so that the plasma acquires the necessary velocity primarily through development of the radial electric field, not collisional friction with the fast ions. We believe that this is the first detailed experimental verification of the so-called $j_{fast} \times B$ prompt torque, although it has been inferred in other experiments.[2] The process is mediated by the neoclassical plasma dielectric response,[3] arising through the bulk ion polarization current driven by the fast radial current injection. Profiles of the toroidal velocity response of the plasma are measured so that the overall angular momentum balance can be compared with the source determined with TRANSP. The ion velocity and temperature are measured using the well-known active charge exchange recombination (CER) spectroscopy technique, which utilizes the applied NBI short "blips".[4] In helium discharges the bulk ion velocity is measured so that there is no uncertainty in the bulk plasma momentum (other than of course statistical errors in the measurement). Not measuring the bulk ion velocity could be a concern when the velocity of a minor impurity constituent is measured, as is often the case experimentally. We have also measured the velocity response of the small intrinsic carbon density in bulk helium discharges and find that the prompt change in toroidal velocity of carbon is similar to that of the bulk helium, consistent with velocities being driven by generation of the radial electric field.

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