Plasma Spin Tames Instabilities in Spherical Torus

Sustained plasmas that simultaneously maintain high beta and high heat confinement are needed for practical energy producing fusion devices. Beta is the ratio of the plasma pressure over that of the magnetic field applied around the axis of the torus. In experiments conducted on the National Spherical Torus Experiment (NSTX) at the DOE Princeton Plasma Physics Laboratory (PPPL), researchers had reported that large plasma spin were observed to co-exist with high plasma beta values (see, Figure 1).

Two-dimensional magnetohydrodynamic (MHD) codes, which do not include the effect of the spin, predict that the MHD modes in the core of plasma will grow and tear the plasma apart. However, the mode growth is observed to saturate and limit further increases in beta, at ~20% higher values than the level permitted when there is no plasma spin. A powerful three-dimensional MHD code M3D is then used to simulate the behavior of the modes. The code carries out fully nonlinear numerical simulations at multiple levels of physics detail, and uses a coding structure that can make effective use of up to a thousand computer processors. The simulations show that the spinning plasma can slow the growth of the most common internal MHD modes (with mode numbers m=n=1) and arrest further growth at a substantial mode amplitude (see, Figure 2). The measured electron temperature (T_e) profile is also mimicked by a simulated measurement of the computed plasma conditions (see, Figure. 3). The MHD mode is calculated to spin with the plasma consistent with the measured magnetic signatures.

Numerical simulations by M3D and other sophisticated codes, together with detailed measurements of the plasma, have shed light on the physics mechanisms of this intriguing phenomenon. While the research is making encouraging progress, further work remains to achieve a comprehensive understanding of the physics of internal mode saturation in strongly spinning high-β_T spherical torus plasmas, which may provide a working model for robust high performance plasmas in future fusion energy devices. An invited talk at the APS meeting on the subject is presented by Jon Menard of PPPL. For more information please contact him (jmenard@pppl.gov), Wonchull Park (wpark@pppl.gov), or Dave Gates (dgates@pppl.gov).

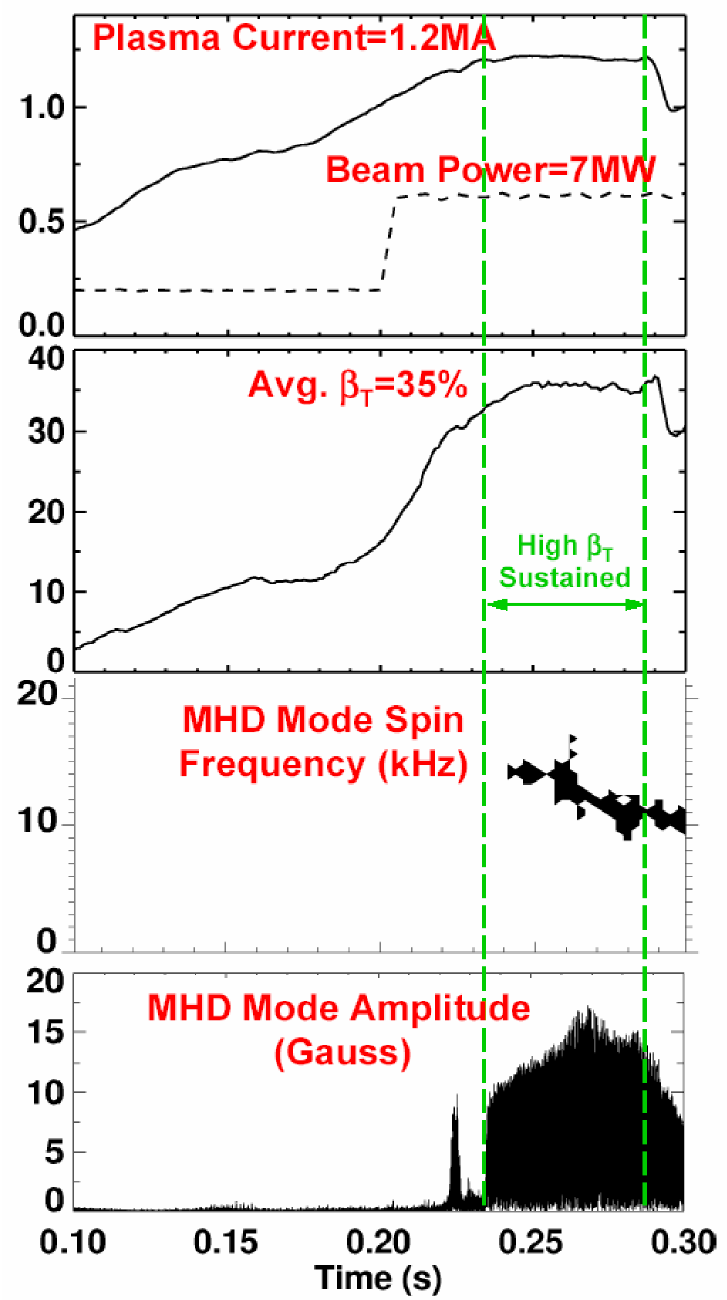

Figure 1. NSTX plasma has shown that very high average beta (where the central beta is around 100%), substantial internal MHD oscillation, and large plasma spin can be maintained simultaneously for several hundred times the expected instability growth time.

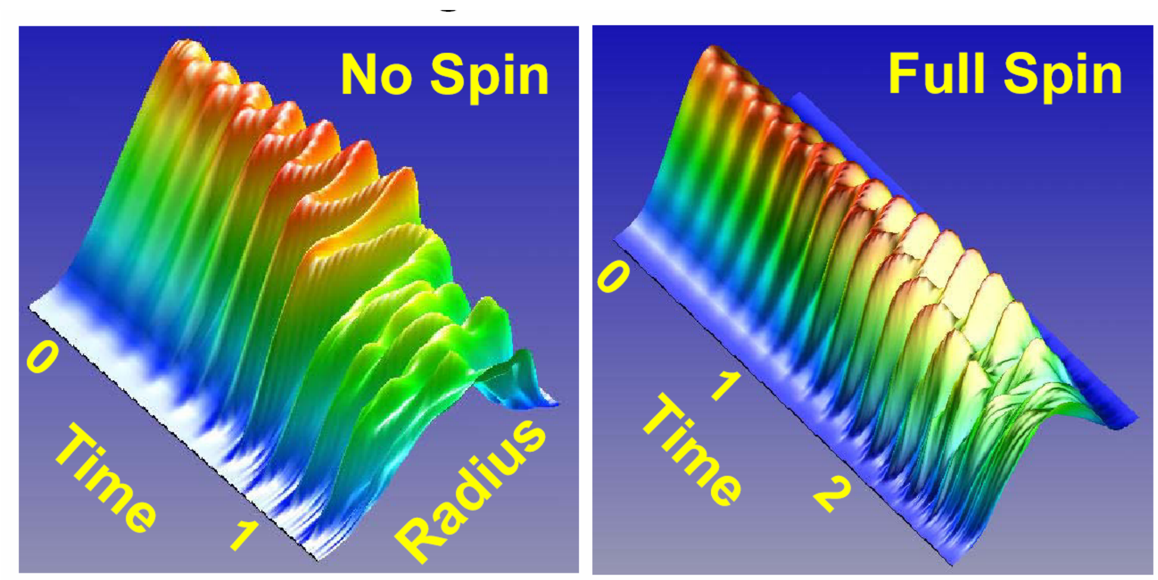

Figure 2. Numerical simulation of the NSTX plasma using the M3D code shows that strong spin can limit the growth of internal MHD instabilities.

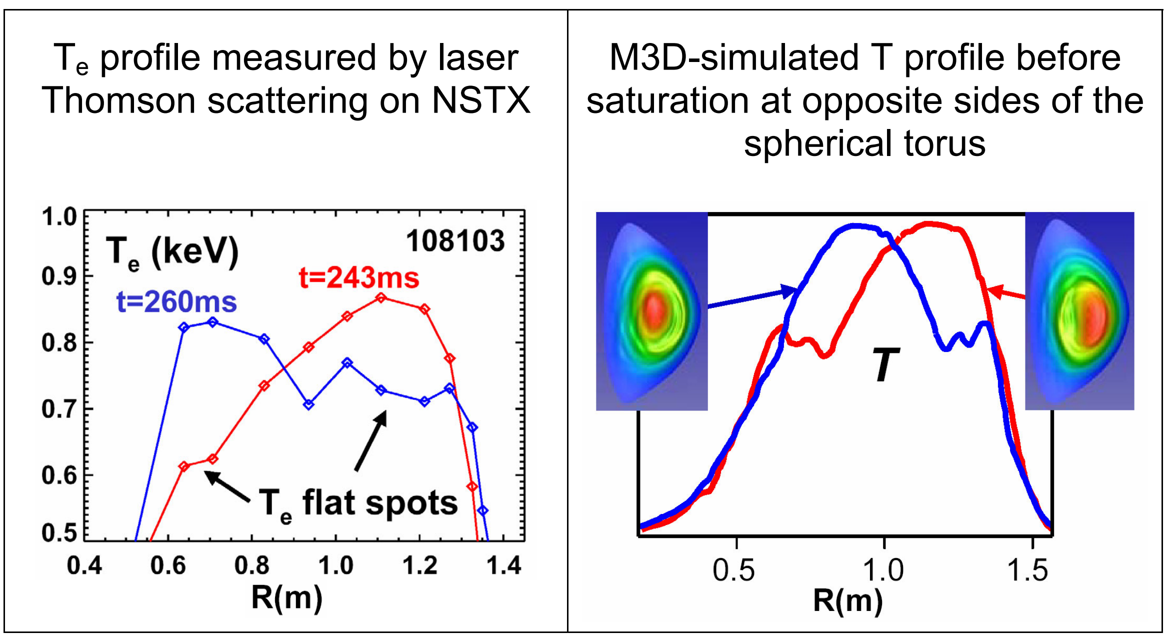

Figure 3: Measured electron temperature (T_e) profile in NSTX indicate a large saturating m=n=1 MHD mode, which are reproduced in the M3D simulation. The inserted pictures are numerical contours of temperature produced by the simulation.