Cross-machine comparison of resonant field amplification and resistive wall mode stabilization by plasma rotation

H. Reimerdes,[1,*] T.C. Hender,[2] S.A. Sabbagh,[1] J.M. Bialek,[1] M.S. Chu,[3] A.M. Garofalo,[1] M.P. Gryaznevich,[2] D.F. Howell,[2] G.L. Jackson,[3] R.J. La Haye,[3] Y.Q. Liu,[4] J.E. Menard,[5] G.A. Navratil,[1] M. Okabayashi,[5] S.D. Pinches,[6] A.C. Sontag,[1] E.J. Strait,[3] W. Zhu,[1] M. Bigi,[2] M. de Baar,[7] P. de Vries,[2] D.A. Gates,[5] P. Gohil,[3] R.J. Groebner,[3] D. Mueller,[5] R. Raman,[8] J.T. Scoville,[3] W.M. Solomon,[5] the DIII-D Team, JET-EFDA Contributors,[†] and the NSTX Team

[1] *Columbia University, New York, New York, USA*

[2] *EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, UK*

[3] *General Atomics, San Diego, California, USA*

[4] *Chalmers University of Technology, Göteborg, Sweden*

[5] *Princeton Plasma Physics Laboratory, Princeton, New Jersey, USA*

[6] *Max-Planck-Institut für Plasmaphysik, Garching, Germany*

[7] *FOM Instituut for Plasmafysica Rijnhuizen, Association EURATOM-FOM, TEC, Nieuwegein, The Netherlands*

[8] *University of Washington, Seattle, Washington, USA*

(Dated: December 20, 2005)

Abstract

Dedicated experiments in the DIII-D and JET tokamaks and the NSTX spherical torus reveal the commonalities of resistive wall mode (RWM) stabilization by sufficiently fast toroidal plasma rotation in devices of different size and aspect ratio. In each device the weakly damped n=1 RWM manifests itself by resonant field amplification (RFA) of externally applied n=1 magnetic fields, which increases with the plasma pressure. Probing DIII-D and JET plasmas with similar ideal magnetohydrodynamic (MHD) stability properties with externally applied magnetic n=1 fields shows that the resulting RFA is independent of the machine size. In each device the drag resulting from RFA slows the toroidal plasma rotation and can lead to the onset of an unstable RWM. The critical plasma rotation required for stable operation in the plasma center decreases with increasing q_{95}, which is explained by the inward shift of q surfaces, where the critical rotation remains constant. The quantitative agreement of the critical rotation normalized to the inverse Alfvén time at the q=2 surface in similar DIII-D and JET plasmas supports the independence of the RWM stabilization mechanism of machine size and indicates the importance of the q=2 surface. At low aspect ratio the required fraction of the Alfvén velocity increases significantly. The ratio of the critical rotation in similar NSTX and DIII-D plasmas can be explained by trapped particles not contributing to the RWM stabilization, which is consistent with stabilization mechanisms that are based on ion Landau damping. Alternatively, the ratio of the required rotation to the sound wave velocity remains independent of aspect ratio.

* `reimerdes@fusion.gat.com`

† See J. Pamela et al., Fusion Energy 2004 (Proc. 20th Int. Conf. Vilamoura, 2004) IAEA, Vienna (2004).