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Numerical Studies of Turbulence in LAPD

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Brett Cory Friedman

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Abstract of the Dissertation

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Professor Troy A. Carter, Chair

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Vita

2007 B.S. (Physics), University of California, Irvine.

Publications

B. Friedman, T. A. Carter, M. V. Umansky, D. Schaffner, and B. Dudson, Energy dynamics in a simulation of LAPD turbulence, Phys. Plasmas, 102307 (2012).

D. A. Schaffner, T. A Carter, G. D. Rossi, D. S. Guice, J. E. Maggs, S. Vincena, and B. Friedman, Modification of Turbulent Transport with Continuous Variation of Flow Shear in the Large Plasma Device, Phys. Rev. Lett. 109, 135002 (2012).

S. Zhou, W. W. Heidbrink, H. Boehmer, R. McWilliams, T. A. Carter, S. Vincena, B. Friedman, and D. Schaffner, Sheared-flow induced confinement transition in a linear magnetized plasma, Phys. Plasmas 19, 012116 (2012).

B. Friedman, M. V. Umansky, and T. A. Carter, Grid convergence study in a simulation of LAPD turbulence, Contrib. Plasma Phys. 52, 412 (2012).

M. V. Umansky, P. Popovich, T. A. Carter, B. Friedman, and W. M. Nevins, Numerical simulation and analysis of plasma turbulence the Large Plasma Device, Phys. Plasmas 18, 055709 (2011).

P. Popovich, M.V. Umansky, T.A. Carter, and B. Friedman, Modeling plasma

turbulence and transport in the Large Plasma Device, Phys. Plasmas 17, 122312 (2010).

P. Popovich, M.V. Umansky, T.A. Carter, and B. Friedman, Analysis of plasma instabilities and verification of the BOUT code for the Large Plasma Device, Phys. Plasmas 17, 102107 (2010).

S. Zhou, W. W. Heidbrink, H. Boehmer, R. McWilliams, T. A. Carter, S. Vincena, S. K. P. Tripathi, P. Popovich, B. Friedman, and F. Jenko, Turbulent transport of fast ions in the Large Plasma Device, Phys. Plasmas 17, 092103 (2010).

B. Friedman, M. V. Umansky, and T. A. Carter, Grid convergence study in a simulation of LAPD turbulence, Contrib. Plasma Phys. 52, 412 (2012).

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