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Annual Progress Report on

LARGE EXPERIMENT DATA ANALYSIS COLLABORATION

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This is the second annual progress on the three-year Large Experiment Data Analysis Collaboration DOE grant DE-FG02-92ER54139, which succeeded a previous four-year grant under the same grant number. This year most of the collaboration effort shifted from being with the TFTR program, to being with the DIII-D program, and most new research focused on the properties, causes and possible amelioration of neoclassical tearing modes. In addition, our studies of nonlocal electron heat transport in TFTR have attracted wider attention, and are now being transferred to similar research on DIII-D. During this grant year the participating personnel and their approximate degree of funded involvement on this research project has been as follows: J.D. Callen (PI: 10% during academic year, 1 summer month); C.C. Hegna (Asst. Sci., 20%); M.W. Kissick (post doc, 75%); and grad students S.E. Kruger (25%), C. Ren (100%).

Neoclassical Tearing Modes [1, 3, 4, 5, 7, 9-11, 12, 16, 19-24, 26, 28, 30]

Neoclassical tearing modes in high performance tokamaks "came of age" this past year, particularly in regard to their likely role in limiting the beta in long-pulse tokamaks such as ITER. Thus, our leadership in the underlying theory and experimental identification of these modes in hot tokamaks became increasingly recognized. As a consequence, we were called upon to give a number of seminar talks on the understanding, experimental diagnosis and effects of neoclassical tearing modes [7, 16, 19, 24, 26, 27, 28]. This past grant year, some of our earlier studies on mode-locking effects on toroidal flow evolution [1], and threshold conditions and bifurcations [4] were published. Also, we contributed significantly to ITER [5] and DIII-D [3, 23] publications concerning these modes and their effects. Further, this past grant year reports were completed (and are in the process of being submitted for publication) on the following neoclassical tearing mode issues: stabilization by localized current drive or heating [8, 21]; mode coupling trigger [10, 19, 20]; influence of geometry [11, 30]; and new internal measurement of delta-prime from electron temperature fluctuations in TFTR [12, 20]. Finally, three reports were submitted (to Bill Nevins of LLNL) for inclusion with the U.S. home team contributions to urgent ITER Physics R&D Long-Pulse Beta Limit issues: 2.1 shaping effects [11]; 2.3 seed-island generation [10]; and 3.2 control scenarios [9]. Throughout the grant year we have been in close contact with R. LaHaye et al. at GA and involved in planning DIII-D experiments to further explore neoclassical tearing modes, their effects and control.

Nonlocal Electron Heat Transport [2, 6, 7, 12, 13, 14, 16, 17, 24, 28]

Our studies on the enigma of nonlocal electron heat transport in TFTR in collaboration with E. Fredrickson et al. [2, 6] are being increasingly recognized. Numerous invited and seminar talks were given on this work this past year [15, 17, 18, 25, 29]. Reports [8, 13, 14] which are in the process of being published were written characterizing the conditions under which the nonlocal effects occur (low density over electron temperature, when electrons are thermally decoupled from the ions?) concomitant MHD 1/1 - mode effects, and possible mechanisms responsible for these effects. Finally, since DIII-D is planning to do ECH-induced transient transport studies during its CY1997 program, we have begun to collaborate with D. Schissel et al. on developing an experimental plan and will work on analyzing the data from these experiments when it becomes available.

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Grant-Related Publications

Journal Articles, Conference Proceedings Papers:

[1]* M. Yokoyama, J.D. Callen, C.C. Hegna, "Effect of Mode Locking on Toroidal Flow Evolution," Nuclear Fusion **36**, 1307 (1996).

[2] M.W. Kissick, J.D. Callen, E.D. Fredrickson, A.C. Janos, G. Taylor, "Non-local Component of Electron Heat Transport in TFTR," Nuclear Fusion **36**, 1691 (1996); Corrigendum **37**, 568 (1997).

[3] R.J. LaHaye, J.D. Callen, M.S. Chu, S. Deshpande, T.A. Gianakon, C.C. Hegna, et al., "Practical Beta Limit in ITER-Shaped Discharges in DIII-D and Its Increase by Higher Collisionality," paper F1-CN-64/AP1-21 at 16th IAEA Fusion Energy Conference, Montreal, Canada, 7-11 October 1996 (Proceedings to be published).

[4]* M. Zabiego, J.D. Callen, "Threshold Condition for Non-Linear Tearing Modes in Tokamaks," Nuclear Fusion **37**, 361 (1997).

[5] O. Sauter, ..., J.D. Callen, T.A. Gianakon, C.C. Hegna et al., "Beta Limits in Long-Pulse Tokamak Discharges," Phys. Plasmas **4**, 1654 (1997).

[6] M.G. Bell, ..., J.D. Callen, M.W. Kissick et al., "Deuterium-Tritium Plasma Regimes in the Tokamak Fusion Test Reactor," Phys. Plasmas **4**, 1714 (1997).

[7] C.B. Forest, J.R. Ferron, T.A. Gianakon et al., "Reduction in Neutral Beam Driven Current in a Tokamak by Tearing Modes," Phys. Rev. Lett. **79**, 427 (1997).

Reports:

[8] M.W. Kissick, J.D. Callen, E.D. Fredrickson, "Further Observations on the Nonlocal Electron Heat Transport Effect on TFTR," UW-CPTC 96-6, August 1996.

[9]* C.C. Hegna and J.D. Callen, "On the Stabilization of Neoclassical MHD Tearing Modes Using Localized Current Drive or Heating," UW-CPTC 96-7, December 1996 (to be published in Phys. Plasmas).

[10]* T.A. Gianakon, C.C. Hegna, and J.D. Callen, "Mode Coupling Trigger of Neoclassical Magnetohydrodynamic Tearing Modes in Tokamaks," UW-CPTC 97-6, May 1997.

[11]* S.E. Kruger, C.C. Hegna, J.D. Callen, "Geometrical Influences on Neoclassical Magnetohydrodynamic Tearing Modes," UW-CPTC 97-10, August 1997.

[12] Chuang Ren, J.D. Callen, Z. Chang, E.D. Fredrickson, T.A. Gianakon, C.C. Hegna, K.M. McGuire, G. Taylor and M.C. Zarnstorff, "Measuring Δ' From Electron Temperature Fluctuations in TFTR," PPPL Report being published, August 1997.

[13] M.W. Kissick, J.D. Callen, E.D. Fredrickson, "Required Conditions For And Coincident 1/1-Mode Activity Associated with the Nonlocal Electron Heat Transport Effect On TFTR," UW-CPTC 97-11, August 1997.

[14]* J.D. Callen and M.W. Kissick, "Evidence and Concepts for Nonlocal Transport," UW-CPTC 97-12, August 1997. (June 1997 EPS Berchtesgaden Meeting invited talk, to be published in Plasma Physics and Controlled Fusion).

Invited Talks:

[15]* J.D. Callen, "Transient Transport, What Do We Learn From It?," Workshop on Transport In Fusion Plasmas, Varenna, Italy, 2-6 September 1996.

[16]* C.C. Hegna, "On the Possibility of Stabilizing Neoclassical Tearing Modes," Workshop on MHD Feedback Stabilization, PPPL, Princeton, NJ, 11-13 December 1996.

[17] M.W. Kissick, "Nonlocal Electron Heat Transport on TFTR," U.S.-European Transport Task Force Workshop, Madison, WI, 23-26 April 1997.

[18]* J.D. Callen, and M.W. Kissick, "Evidence and Concepts for Nonlocal Transport," 24th EPS Conference on Controlled Fusion and Plasma Physics, Berchtesgaden, Germany, 9-13 June 1997.

Meeting Presentations:

[19]* Three talks (Callen, "Neoclassical MHD -- Applicability and Limitations;" Gianakon, "Mode Coupling Excitation of Neoclassical Tearing Modes;" Hegna, "Parallel Transport Effects on Non-Linear Tearing Modes") at MHD Working Group Meeting, Denver, CO, November 10, 1997.

[20]* Two posters (1R8/Ren, "Response of a Rotating Plasma to a Resonant Boundary Perturbation;" 1R10/Gianakon, "Mode Coupling as a Trigger for Neoclassical-MHD Driven Magnetic Islands in a Tokamak Plasma"), at DPP-APS Meeting, Denver, CO, 11-15 November 1996.

[21] One talk (Ren, "Measuring Delta-Prime From TFTR Jog Data") at MHD Working Group Meeting, Madison, WI, 27 April 1997.

[22]* Two posters (1C34/Ren, "Nonlinear Stability of Tearing Modes," 1D13/Gianakon et al., "Simulations of the Feedback Stabilization of Neoclassical MHD Tearing Modes") at Sherwood Theory Conference, Madison, WI, 28-30 April 1997.

[23] One poster (P3.074/R.J. LaHaye, J.D. Callen, T.A. Gianakon, C.C. Hegna, L.L. Lao, C. Ren et al., "Metastable Beta Limit in DIII-D) at 24th EPS Conference on Controlled Fusion and Plasma Physics, Berchtesgaden, Germany, 9-13 June 1997.

Seminars And Other Presentations:

[24]* J.D. Callen, "Nonlinear Evolution of Tearing Modes in Tokamaks," JET Science Seminar, Abingdon, England, 29 August 1996.

[25] J.D. Callen, "Transient Transport Studies," Plasma Seminar, UW-Madison, 3 February 1997.

[26]* C.C. Hegna, "Beta Limits in Long Pulse Tokamaks," First IAE International Symposium on Advanced Energy, Kyoto University, Kyoto, Japan, 20 February 1997.

[27]* J.D. Callen, "Neoclassical Tearing Modes in Tokamak Plasmas," NEEP Colloquium, UW-Madison, 4 March 1997.

[28]* C.C. Hegna, "The Physics of Neoclassical Tearing Modes in Tokamaks," JAERI, Naka, Japan, 27 March 1997.

[29] M.W. Kissick, "Nonlocal Electron Heat Transport on TFTR," Transport Group Seminar, General Atomics, San Diego, CA, 13 June 1997.

[30] C.C. Hegna, "Geometrical Influences on Pressure Driven Magnetic Islands in Tokamaks," MHD Group Seminar, General Atomics, San Diego, CA, 23 July 1997.

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