DPP09-2009-000390

Abstract for an Invited Paper
for the DPP09 Meeting of
the American Physical Society

Fluctuation-Induced Particle Transport and Density Relaxation in a Stochastic Magnetic Field[1]

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Particle transport and density relaxation associated with electromagnetic fluctuations is an unresolved problem of long standing in plasma physics and magnetic fusion research. In toroidal fusion plasmas, magnetic field fluctuations can arise spontaneously from global MHD instabilities, e.g., tearing fluctuations associated with sawtooth oscillations. Resonant magnetic perturbations (RMP) have also been externally imposed to mitigate the effect of edge localized modes (ELMs) by locally enhancing edge transport in Tokamaks. Understanding stochastic-field-driven transport processes is thus not only of basic science interest but possibly critical to ELM control in ITER. We report on the first direct measurement of magnetic fluctuation-induced particle transport in the core of a high-temperature plasma, the MST reversed field pinch. Measurements focus on the sawtooth crash, when the stochastic field resulting from tearing reconnection is strongest, and are accomplished using newly developed, laser-based, differential interferometry and Faraday rotation techniques. The measured electron particle flux, resulting from the correlated product of electron density (δn) and radial magnetic fluctuations (δb_r), accounts for density profile relaxation during these magnetic reconnection events. Surprisingly, the electron diffusion is 30 times larger than estimates of ambipolarity-constrained transport in a stochastic magnetic field. A significant ion flux associated with parallel ion flow velocity fluctuations ($\delta v_{i,//}$) correlated with δb_r appears responsible for transport larger than predictions from the quasi-linear test particle model. These results indicate the need for improved understanding of particle transport in a stochastic magnetic field. Work performed in collaboration with W.X. Ding, W.F. Bergerson, T.F. Yates, UCLA; D.J. Den Hartog, G. Fiksel, S.C. Prager, J.S. Sarff and the MST Group, University of Wisconsin-Madison.

[1]Work supported by US Department of Energy.