IAEA FEC 2014

Contribution ID: **656** Type: **Oral**

Controlling H-Mode Particle Transport with Modulated Electron Heating in DIII-D and Alcator C-Mod via TEM Turbulence

Wednesday 15 October 2014 11:45 (20 minutes)

This work develops a quantitative understanding of the mechanisms for increased particle transport with electron heating in (quiescent) H-mode plasmas. Our DIII-D experiments demonstrate that H-mode core particle transport and density peaking can be locally controlled by modulated electron cyclotron heating (ECH). GYRO simulations show density gradient driven trapped electron modes (TEM) are the only unstable drift modes in the inner half-radius. Transport driven by TEMs increases strongly with electron temperature, reducing the density gradient during ECH. Thus α heating could reduce density peaking, self-regulating fusion power. The DIII-D experiments complement Alcator C-Mod experiments which controlled H mode core particle transport with modulated minority ICRF heating. High-resolution profile reflectometer density profiles and local fluctuation measurements were obtained in DIII D. Core density fluctuations intensify during electron heating in both C-Mod and DIII-D at TEM wavelengths. Several hundred GS2 nonlinear TEM simulations for Alcator C-Mod reproduce measured core density fluctuation levels using a new synthetic diagnostic, while matching inferred energy fluxes. A nonlinear upshift in the TEM critical density gradient, associated with zonal flow dominated states, increases strongly with collisionality. In the C-Mod experiments, the density gradient is clamped by this nonlinear TEM critical density gradient. The DIII-D experiments test our predicted strong collisionality variation of the TEM nonlinear upshift at an order of magnitude lower collisionality, while allowing Te/Ti to nearly double during ECH, tripling the TEM growth rate. Intermittent, quasi-coherent DBS fluctuations near ρ~0.33 grow stronger with ECH, with adjacent toroidal mode numbers characteristic of TEMs, accompanied by broadband turbulence. Density fluctuations from beam emission spectroscopy near ρ~0.7 strongly increase. Core carbon density and metallic line intensities are modulated by ECH, consistent with TEM expectations. Finally, profile stiffness tests were performed via gas puff modulation that varied the density gradient as well as collisionality.

Supported by the U.S. Department of Energy under DE-FC02-08ER54966, DE-FC02-04ER54698, DE-AC02-09CH11466, DE-FG02-08ER54984, DE-FG02-07ER54917, DE-FG02-99ER54531, DE-FG02-89ER53296, DE-FG02-08ER54999, and DE-FC02-99ER54512.

Country or International Organisation

USA

Paper Number

EX/2-3

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Session Classification: Core Turbulence