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Energetic-particle-driven instabilities and induced fast-ion transport in a reversed field pinch[1]

LIANG LIN, UCLA

Multiple bursty energetic-particle (EP) modes with fishbone-like structures are observed during 1 MW tangential neutral-beam injection into MST reversed field pinch (RFP) plasmas. The distinguishing features of the RFP, including large magnetic shear (tending to add stability) and weak toroidal magnetic field (leading to large fast ion beta and stronger drive), provide a complementary environment to tokamak and stellarator configurations for exploring basic understanding of these instabilities. Detailed measurements of the EP mode characteristics and temporal-spatial dynamics reveal their influence on fast ion transport and interaction with global tearing modes. Internal magnetic field fluctuations associated with the EP modes are directly observed for the first time by Faraday-effect polarimetry (frequency $\sim$ 90 kHz and amplitude $\sim$ 2 G). Simultaneously measured density fluctuations exhibit a dynamically evolving and asymmetric spatial structure that peaks near the core where fast ions reside and shifts outward as the instability evolves. Furthermore, the EP mode frequencies appear at $\sim k_{\|} V_A$, consistent with continuum modes destabilized by strong drive. The fast-ion temporal dynamics, measured by a neutral particle analyzer, resemble a classical predator-prey relaxation oscillation. It contains a slow-growing phase arising from the beam fueling followed by a rapid drop ($\sim$ 15%) when the EP modes peak, indicating the fluctuation-induced transport maintains a stiff fast-ion density profile. The inferred transport rate is strongly enhanced ($\times 2$) with the onset of multiple nonlinearly-interacting EP modes. The fast ions also impact global tearing modes, reducing their amplitudes by up to 65%. This mode reduction is lessened following the EP-bursts, further evidence for fast ion redistribution that weakens the suppression mechanism. Possible tearing mode suppression mechanisms will be discussed.

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