Mapping and Uncertainty Analysis of Energy and Pitch Angle Phase Space in the DIII-D Fast Ion Loss Detector*

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Abstract. New phase space mapping and uncertainty analysis of energetic ion loss data in the DIII-D tokamak is providing experimental results that can serve as valuable constraints in first-principles simulations of energetic ion transport. Beam ion losses are measured by the fast ion loss detector (FILD) diagnostic system consisting of two magnetic spectrometers placed independently along the outer wall. Beam ions reaching these detectors strike the internal scintillator plate according to their energy and pitch angle. The tokamak magnetic field at the detector determines the ultimate measurable phase space and uncertainty of the FILD. That diagnostic sensitivity changes as the tokamak (applied toroidal field) and plasma parameters evolve (plasma current). Full shot data is processed by calculating the local magnetic field vector based on equilibrium reconstructions to determine the energy/pitch mapping across the scintillator, which is then used to convert CCD camera images into loss amplitudes as a function of energy and pitch. Since the camera observes the entire scintillator, this provides a complete catalog of beam ion losses limited only by the camera frame rate of $100 \leq f \leq 160$ Hz. This technique is well suited to studies of beam ion loss resulting from the application of resonant magnetic perturbations (RMPs) in which the RMP is driven as a 25 Hz rotating field and beam ion losses can be calculated by simulations incorporating different plasma response models for the applied field. Monte Carlo simulations of mono-energetic and single-pitch ions reaching the FILDs are used to determine the expected uncertainty in the measurements. Modeling shows that the variation in gyrophase of 80 keV beam ions at the FILD aperture can produce an apparent measured energy signature spanning across the 50 - 140 keV range of the strike map. These calculations compare favorably with experiments in which neutral beam prompt loss provides a well known energy and pitch distribution. This information is vital to simulation codes that seek to describe energetic ion transport resulting from Alfvén eigenmodes (AEs) in which ion/wave resonances exhibit sensitive dependencies on ion energy and pitch. The analysis method and case studies from the RMP and AE experiments will be shown.

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