Enhanced Localized Energetic Ion Losses Resulting from First-orbit Linear and Nonlinear Interactions with Alfvén Eigenmodes in DIII-D

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Abstract. Two key insights into interactions between Alfvén eigenmodes (AEs) and energetic particles in the plasma core are gained from measurements and modeling of first-orbit beam-ion loss in DIII-D. First, the neutral beam-ion first-orbit losses are enhanced by AEs and single AE can cause large fast-ion displacement. The coherent losses are from born trapped full energy beam-ions being non-resonantly scattered by AEs unto loss orbits within their first poloidal transit. The loss amplitudes scale linearly with the mode amplitude but the slope is different for different modes. The radial displacement of fast-ions by individual AE can be directly inferred from the measurements. Second, oscillations in the beam-ion first-orbit losses are observed at the sum, difference and harmonic frequencies of two independent AEs. These oscillations are not plasma modes and are absent in magnetic, density, and temperature fluctuations. The origin of the non-linearity as a wave-particle coupling is confirmed through bi-coherence analysis, which is clearly observed because the coherences are preserved by the first-orbit loss mechanism. An analytic model and full orbit simulations show that the non-linear features seen in the loss signal can be explained by a non-linear interaction between the fast ions and the two independent AEs.

PACS Numbers: 52.55.Pi, 52.35.Mw, 52.35.Bj, and 52.55.Fa