5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Improvement of Critical Gradient Model and Alpha Particle Redistribution Prediction for CFETR Steady State Operation

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Based on the critical gradient model (CGM), the combination of the TGLFEP and EPtran codes is employed to predict energetic particle (EP) transport induced by Alfvén eigenmodes (AEs). To be consistent with the experiment, recent improvements to the model include consideration of threshold evolution and orbit loss mechanisms. The threshold is modified to be the normalized critical gradient (a/n dn/dr) instead of the critical gradient (dn/dr), and the new threshold is defined as a function inversely proportional to the EP density as obtained by the TGLFEP code. Additionally, the EP loss cone calculated by ORBIT has been added into the EPtran code, which provides an important additional core loss channel for EPs due to finite orbits. With these two improvements, the EP redistribution profiles have been found to very well reproduce the experimental profiles of two DIII-D validation cases (#142111 and #153071) with multiple unstable AEs and large-scale EP transport. As an application of the improved CGM, α particle redistribution is predicted for CFETR steady state scenario. With multiple (n=1-10) unstable TAEs, three identified transport mechanisms, namely, background turbulent transport, radial transport induced by unstable AE, and losses due to finite orbit width effect, are analyzed separately and also evaluated in combination. Each mechanism by itself only causes slight EP loss, but the combination raises the lost fraction up to ~6.6%. Avoiding significant overlap between the AE unstable region and the loss cone is a key factor for minimizing EP loss.

References

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