The influence of toroidicity and partially ionized atomic impurities on runaway electron avalanche in tokamak plasmas

Nathan A. Garland, Qi Tang, Christopher J. McDevitt, Zehua Guo and Xian-Zhu Tang[1]

[1]*Los Alamos National Laboratory, Los Alamos, NM 87545, USA*

We present an overview of how toroidicity and enhanced scattering of atomic impurities impact runaway electron avalanche formation, and subsequent runaway electron energy distributions, in fusion scenarios. This study was performed via the relativistic Fokker-Planck kinetic equation in slab and bounce-averaged forms [1] to capture the effects of toroidal geometry. Enhanced electron scattering and drag via interaction with ionized impurities is included through appropriate collision frequency modifications [2], while secondary electron generation is modeled via the enhancement of the Møller cross-section [3].

It is known that toroidicity and impurity content enhances the threshold field for avalanche, but the momentum-space origins of this effect are largely unknown. By probing the field threshold for avalanche formation in ITER-like fusion plasmas, we show that both toroidicity and electron scattering with ionized impurities significantly impact the structure of the runaway electron momentum space geometry required for avalanche formation. By examining the topology of the seed distribution at the avalanche formation threshold, we observe clear changes to the vortex structure required for avalanche. Key features of this study are the coupled nature of the separatrix X-point and vortex O-point energies, which broaden the runaway vortex necessary to capture secondary electrons generated at low energies.

Further, we present how the runaway electron energy distribution function is shaped under the influence of toroidicity and impurity scattering. For a given electric field above avalanche formation, it is found alongside damping of the runaway electron mean energy, significant attenuation of the runaway distribution tail is introduced. The impact of the trapping region introduced by toroidicity, enhanced by impurity driven pitch-angle scattering, is shown to have increased impact on runaway electron dynamics at high field values above threshold. This work was supported by DOE OFES.

References

[1] Guo et al. Plasma Phys. Control. Fusion 59 044003 (2017)

[2] Hesslow et al. Phys. Rev. Lett. 118 255001 (2017)

[3] McDevitt et al. Avalanche Mechanism for Runaway Electron Amplification in a Tokamak Plasma (In review)