Contribution ID: **150** Type: **Invited**

# Runaway electron energy control via wave-particle interaction

Wave-particle interaction (WPI) can produce effective pitch-angle scattering for electrons under runaway acceleration by the parallel inductive electric field. Enhanced pitch-angle scattering can impact the runaway energy gain in two ways. The first is entirely in momentum space, in which the resonant pitch-angle scattering sets up an energy barrier for electrons that follows the resonant condition in electron energy and pitch as a function of wave frequency and parallel wave-number. The underlying physics is a competition between electric field acceleration and pitch angle scattering. Acceleration by parallel electric field dominates at small pitch, but becomes subdominant compared with synchrotron radiation damping for large enough pitch. Rapid increase in pitch through resonant WPI can thus turn accelerating electrons at low pitch to a slowing-down population at high pitch, which effectively reshapes the runaway vortex to much lower energy that is set by the resonance condition in momentum and pitch space. This is a robust process as long as a strong magnetic field is present so synchrotron damping is appreciable at high pitch or a finite aspect ratio of the flux surface allows a sizable trapped region in momentum space.

While a beam-like runaway distribution is known to excite fast plasma waves through the anomalous Doppler-shifted cyclotron resonance, and the saturation of this velocity space instability modifies the runaway energy distribution, external injection of specially designed fast electromagnetic waves (˜500 MHz) has the advantage of targeting the runaways at energies of 1 MeV or below. This is because the damping of the wave, as opposed to excitation of a wave instability, is through the normal Doppler-shifted cyclotron resonance.

The second way resonant and non-resonant WPI can limit the runaway electron energy is through enhanced spatial transport even if the magnetic surfaces are intact. Only passing electrons can experience runaway acceleration, and the maximum energy gain after each toroidal transit is simply the loop voltage so the runaway energy is bounded from above by the number of toroidal turns of a passing runaway electron before it hits the wall. The dwell time of a passing electron is thus directly tied to the maximum energy it can reach under runaway acceleration. This picture is complicated by the fact that passing electrons can become trapped as the result of enhanced pitch angle scattering. Such trapped energetic electrons no longer experience runaway acceleration while suffering much faster radial loss.

Experimental observation on DIII-D suggests that compressional Alfven waves (CAE) in the MHz range are correlated with the runaway plateau, which motivated the question if and how external CAE injection can provide runaway control.

Three key issues in these approaches are (1) collisional damping of the externally injected wave; (2) flux surface averaged wave-spectrum that enters the quasilinear pitch angle scattering coefficient, which helps set the power efficiency of the scheme, and (3) how non-resonant WPI in CAE range modifies runaway transport. With the helicon and CAE wave systems coming online on DIII-D, we will investigate how these injected waves can provide energy control for the runaways.

## Member State or International Organization

United States of America

## Affiliation

Los Alamos National Laboratory

**Primary authors:** TANG, Xianzhu (Los Alamos National Laboratory); GARLAND, Nathan (Los Alamos National Laboratory); TANG, Qi (Los Alamos National Laboratory); GUO, Zehua (Los Alamos National Laboratory); MCDEVITT, Christopher (University of Florida); PAZ-SOLDAN, Carlos (General Atomics); LIU, Chang (Princeton Plasma Physics Laboratory)

**Presenter:** TANG, Xianzhu (Los Alamos National Laboratory)

**Track Classification:** Mitigation