# Nonlinear saturation of toroidal Alfven eigenmode by zonal fields in DIII-D plasmas

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Toroidal Alfven eigenmode (TAE) has been found to induce large energetic particle (EP) transport in tokamaks and stellarators. In order to predict the nonlinear saturation amplitude of TAE which determines the EP transport level in burning plasmas such as ITER, we need to understand the TAE nonlinear saturation mechanisms, which could be complicated by the wave-wave and wave-particle interactions, non-perturbative effects, and toroidal geometry.

A recent linear gyrokinetic simulation of TAE shows the up-down symmetry of the ideal MHD mode structure is broken by the non-perturbative EP contribution, which introduces the radial symmetry breaking due to the radial variations of EP pressure gradients [1]. This finding successfully explains the experiment observation of DIII-D discharge #142111.

In this work, we carried out the nonlinear gyrokinetic simulation of the TAE for the same DIII-D shot. We found that dominant TAE saturation mechanism is the shearing of zonal flow. The effects of zonal current is much smaller than the zonal flow. Zonal fields (zonal flow and zonal current) are nonlinearly forced driven by the TAE three-wave couplings with a growth rate twice the linear TAE growth rate. Localized current sheets with $k_{||} = 0$ but finite toroidal mode number $n$ are nonlinearly generated with a growth rate about 3 times of linear TAE growth rate. These current sheets are driven by a nonlinear ponderomotive force (dynamo effects in MHD terminology) and can lead to nonlinearly-driven tearing instabilities as recently observed in MHD-gyrokinetic hybrid simulations [2]. When zonal fields are removed in the simulation, the TAE mode structures are eventually broken up by nonlinear $E\times B$ convection, which gives a much higher saturation amplitude compared to the case with zonal fields.

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