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Fast electron generation during tokamak startup: experiments and simulations in the TCV tokamak

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Prior to the establishment of fusion-relevant conditions, tokamak plasmas must undergo the breakdown, burn-through, and ramp-up phases. This talk will present recent work at the TCV tokamak aimed at a better characterization and understanding of the dynamics of the burn-through phase both through experiments and simulations. In particular, the conditions giving rise to a significant amount of fast electrons during the startup phase has come under scrutiny. Scans in prefill pressure and gas fueling after the breakdown have been performed. TCV counts with a unique set of fast-electron diagnostics from several X-ray diagnostics to multiple ECE systems allowing detailed observations of non-thermal electrons. It is observed that prefill pressure changes can have a significant effect on the early burn-through plasma dynamics but do not lead to significant changes in the flat-top fast electron population. Gas fueling scans revealed that the plasma density has a direct impact on the onset of fast electrons and can be used as an active control knob to avoid startup fast electrons. The gas fueling timing has also been scanned showing that if the gas is injected too late, fast-electrons remain and could potentially increase in number due to avalanche processes.

These experimental scans are being modelled by the 0D burn-through simulator: STREAM [1]. This code solves for energy and particle balance fluid equations in 0D including a basic circuit equation and impurity screening effects. STREAM includes a self-consistent model for the generation and loss of runaway electrons using sources and loss terms consistent with the presence of partially ionized impurities during the burn-through phase. New observables such as Langmuir probe data to quantify the open-closed field line transition and ion temperature measurements from high resolution spectroscopy allow to constrain simulation input parameters and better validate the modeling results. Fast camera measurements of the early burn-through phase allow estimates of the plasma volume to be used in simulation which are consistent with experiments in contrast with Townsend theory volume estimates.

References:

[1] Hoppe M., J. Plasma Phys. Vol 88, Issue 3 (2022)

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