Early-detection and imaging of birth, growth, saturation and suppression of runaway electrons in the MST tokamak plasma

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Detailed properties of the early detection, imaging and time evolution of the emission from runaway electrons (RE) have been studied using a multi-energy soft x-ray (ME-SXR) pin-hole camera installed at the Madison Symmetric Torus (MST). REs are now also generated at MST in steady tokamak scenarios with low current and toroidal magnetic field obtaining plasmas with core temperatures and densities of the order of 0.1 keV and 0.1×10^{19} m^{-3}. Density thresholds for both runaway electron onset and suppression are determined with simple variations in gas puffing, and the presence of runaways is usually detected via emission of non-thermal x-ray photons and the use a fast single-diode measurement. The use of the novel silicon ME-SXR pin-hole camera allows for a significant improvement in signal-to-noise-ratio (SNR) thus circumventing previous challenges encountered in early detection, 1D imaging, time-evolution and energy discrimination of REs. These observations were made at ratios of photon energies to central Maxwellian background temperatures of the order of $E_{x,\gamma}/T_{e,0}$~20-250. This is of great advantage over conventional REs studies conducted in large tokamaks with electron temperatures of few "keV" and electron energies up to 2-30 MeV, with $E_{x,\gamma}/T_{e,0}$~1000-30000. The main benefits are the early identification and imaging of both the birth and avalanche processes at low-energies in comparison to that at much higher supra-thermal speeds. The time evolution of the total-counts-in-frame - clearly distinguishing the emission from the plasma startup to that of the RE during the current flattop - is shown in Fig. 1-a). The spatially resolved brightness profiles during the birth, growth, saturation and disruption are shown next; these profiles have interesting features changing from hollow to peaked to hollow again before the disruption, a process which is currently under investigation. Data will be presented showing the effect of density thresholds and resonant magnetic perturbations (RMPs) with poloidal mode number m=3 for the onset and suppression of runaway electrons. *This work is supported by the U.S. DOE-OFES under contract number DE-AC02-09CH11466 and LFDA's 2015 DOE Early Career Award Research Program. The experiments were conducted at the Wisconsin Plasma Physics Laboratory (WiPPL), a research facility supported by the DOE-OFES under contract DE-SC0018266 with major facility instrumentation developed with support from the NSF under award PHY 0923258. The MST tokamak thermal quench program is funded under DOE-OFES award DE-SC0020245.*

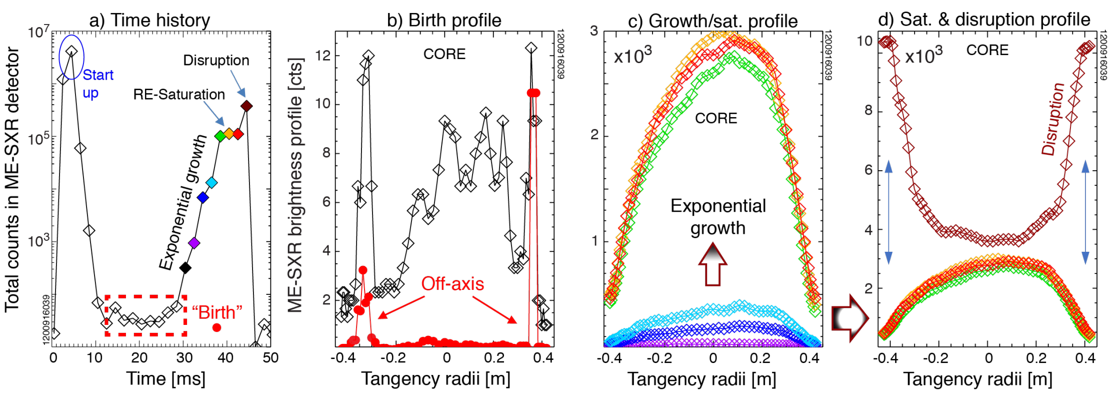

Fig. 1. a) Time evolution of the total counts in frame and brightness profiles during the birth, growth, saturation and disruption in tokamak scenarios at MST.