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Adaptive energy-sensitive x-ray cameras for the record long-pulse at WEST

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The WEST superconducting tokamak features a full tungsten environment and is equipped with an actively cooled ITER-grade divertor providing valuable input for future operation at ITER. Versatile multi-energy soft and hard X-ray pinhole cameras have been developed, calibrated, deployed and operated for long-pulse plasmas at WEST. These cutting-edge instruments, serving as novel enabling technologies, have facilitated investigations into a wide array of phenomena including particle, impurity, and thermal transport, heating and RF current-drive mechanisms, equilibria, MHD physics, and the diagnosis of non-Maxwellian effects such as runaway electrons (RE). This innovative imaging diagnostic leverages a pixelated x-ray detector capable of independently adjusting the lower energy threshold for photon detection on each pixel. The primary detector employed is a PILATUS3 100K, equipped with 0.45 mm Si and 1.0 mm CdTe sensors, enabling sensitivity to photon energies ranging from 1.6 to 30 keV and 20 to 200 keV, respectively. Through meticulous trimming and calibration of the lower energy thresholds, our team has successfully mitigated contributions from radiative recombination and line emissions from medium to high-Z impurities like tungsten. Central electron temperature values are thus derived by modeling the slope of continuum radiation, extracted from ratios of inverted radial emissivity profiles across multiple energy ranges, without relying on a-priori assumptions of plasma profiles, magnetic field reconstructions, high-density limitations, or shot-to-shot reproducibility. Recent breakthroughs include the temporal evolution measurement of central temperature in quasi non-inductive scenarios during the C9 campaign at WEST, encompassing long-pulse L-modes (H98y,2 ~ 1.0) with a stationary central electron temperature of ~4 keV for up to 6 minutes with a total injected energy of up to 1.14 GJ. Time-intensive computer calculations also confirmed good agreement between relevant High Fidelity Plasma Simulator (HFPS) and the measurements indicating a flat central electron temperature of about 4 keV. Novel calculations of the local radiated power density profiles from photon-counting measurements in several energy bands are also now feasible. The possibility of measuring steady state tungsten transport in long-pulse scenarios –without the need of perturbative experiments - will also be discussed for the first time.

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