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SPARC x-ray crystal spectroscopy for ion temperature and toroidal rotation measurements

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High-resolution x-ray crystal spectroscopy has been a workhorse on numerous tokamaks to measure the ion temperature and toroidal rotation profiles from the Doppler broadening and shift, respectively, of intrinsic or seeded impurity line radiation emission. SPARC will be a first-of-its-kind tokamak that will similarly employ this diagnostic. The unique high electron temperature and high neutron flux environment of SPARC has been driving factors for the engineering design. Presented is the performance of the envisaged system of spectrometers optimized to view the Ne-like Xe 3D line (λ≈2.72 Å) for low-temperature operations (T_{e0}≈4-10 keV) and the He-like Kr w resonance line (λ≈0.94 Å) for high-temperature operations (T_{e0}>10 keV). The Flexible Atomic Code (FAC) has been utilized to calculate line intensities, including satellites and polluting tungsten lines. The throughput has been calculated ensuring integration times on the order of the expected energy confinement time, ∼100ms. This workflow has been validated against measured spectra from an absolutely calibrated von Hamos as well as a Johann spectrometer installed on Alcator C-Mod to good agreement. While the number of lines-of-sight is highly constrained, the staged installation of beamlines over the first campaigns minimizes error in calculated fusion power from the reconstructed profiles.

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