Prompt inference of safety and current-density profiles for tokamak advanced scenario research

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Accurate evaluation of the tokamak safety factor and current density profiles requires post-processing associated with equilibrium reconstruction constrained by various diagnostics data. The motional Stark effect (MSE) diagnostic system in KSTAR, operational since 2015, has gone through various calibration and uncertainty assessment procedures, some of which are reactor-relevant such as Faraday rotation in superconducting tokamaks, in-situ subtraction of polarized background light, and multiple-ion-source injection [1, 2, 3, 4]. The improvement in this regard enables it to produce relatively prompt evaluation of these profiles only with global equilibrium data available shot-by-shot. Such direct profile information has been of great help in preparing and interpreting scenario-related experiments in particular. Several important physical issues have been studied based on the profiles of magnetic pitch angle and safety factor that the MSE measurements produce. These include the full-reconnection model validation on the sawtooth instabilities [5, 6, 7] and the internal transport barrier physics [8, 9].

The figure below illustrates the time evolution of the quantities measured and inferred by the MSE system from two different KSTAR discharges with the plasma current of 600 kA – One with the toroidal field of 1.9 T (Shot #28141) and the other with 2.9 T (Shot #28138). The top plots show the tangent of the MSE polarization angle (‘tgamma’) which is used as internal magnetic constraints in the magnetic equilibrium reconstruction calculations, the middle and the bottom plots are for the safety factor and the current density, respectively, both of which are directly inferred from the MSE pitch angle based on theoretical modelling [10]. All of these quantities are consistent with the change of the toroidal field with the same plasma current; (1) Top plots: the pitch angle range shrinks at a higher toroidal field, indicating reduced magnetic pitch angles, (2) Middle plots: higher edge safety factor at the higher field with the central values comparable with those at the lower field since there is no particular mechanism to induce any perturbation in the central part such as off-axis current drive, and (3) Bottom plots: a more peaked current profile with reduced edge current is observed at the higher field following the safety factor profiles reversely. The prompt inference on the MSE-related information will be extended to be real-time once the real-time instrumentation is settled down, which is underway [11, 12].

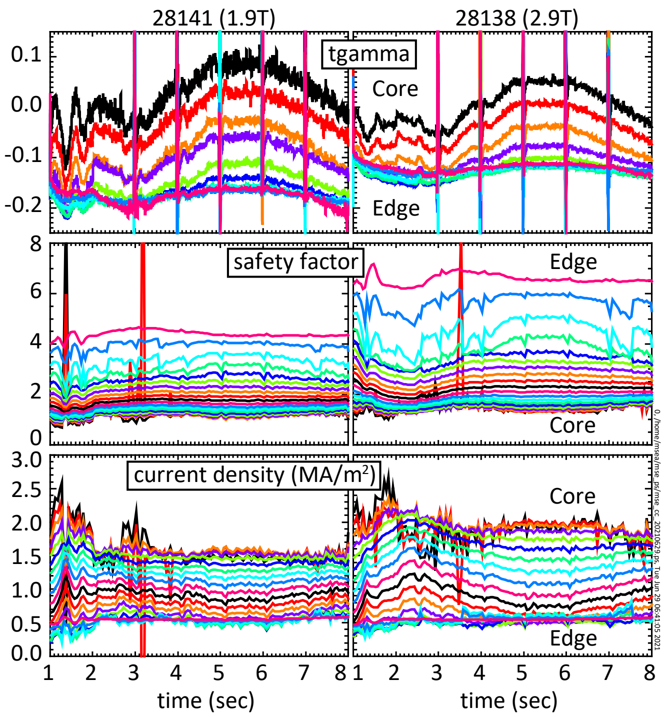

Figure. Example of the KSTAR MSE measurements – Time evolution of the tangent of the MSE pitch angle (Top), the safety factor (Middle), and the current density (Bottom) for two different (28141 and 28138) KSTAR discharges. The large spike every second starting from 2 sec in the ‘tgamma’ plots is a noise measured at the ‘beam-off’ time.

References

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