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Non-axisymmetric Radiation Modeling of JET SPI Discharges Using Emis3D

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Precise values for radiated power during tokamak disruptions are required to predict the effectiveness of mitigation techniques at preventing damage in net energy tokamaks like ITER and SPARC. Conventional approaches to calculating P_{rad} on JET assume a toroidally symmetric radiation source to allow fitting from foil bolometer arrays at two toroidal locations, which is otherwise an underdetermined problem. In mitigated disruptions, 3D MHD modes and localized impurity sources may break toroidal symmetry. To incorporate toroidally asymmetric structures in P_{rad} calculation, the Emis3D radiation modeling code introduced here adopts a physics motivated guess-and-check approach, comparing experimental bolometry data to synthetic data from absolutely calibrated candidate emissivity structures. Candidates are observed with the Cherab modeling framework [M. Carr et al. EPS 2017] and a best fit chosen using a reduced χ^2 statistic. An uncertainty bar is derived by considering all models within two standard deviations of the best fit (the "uncertainty pool"), using bolometer channel errors of 10% of the maximum brightness at each timestep. The resulting uncertainty pool is sensitive to changes in the uncertainty quantification formalism, but the best fit is a robust finding. 2D tomographic inversions are tested, as well as helical structures and 3D MHD simulated distributions from the JOREK code [Huysmans et al. NF 47, 2007]. Two discharges in JET terminated by nominally identical pure neon shattered pellets carrying 2.46×10^{22} Ne atoms are analyzed using Emis3D (95709 and 95711). 2D tomographic inversions are built in 1ms intervals from the time of peak radiation through the current quench. These inversions are the best fit at these times, although helical distributions are within the uncertainty pool, introducing large lower error bars on P_{rad}. Helical radiation structures are found to fit the pre-thermal quench (pre-TQ) best and exhibit a parallel flow towards the high-field side consistent with the magnetic nozzle effect and with JOREK simulations. Candidates from JOREK simulations are not found within the uncertainty pool, although this result is sensitive to the uncertainty quantification formalism. Improvements in the agreement between JOREK and the pre-TQ bolometry data were found by reducing the toroidal extent of the impurity source used in the simulation. On 95709 and 95711, radiated fractions of $f_{rad} = 0.95 + 0.05/-0.31$ and $f_{rad} = 0.98 + 0.02/-0.26$, of the plasma stored energies 11.5 and 11.7 MJ respectively, are found, suggesting that the thermal and magnetic energy may have been fully mitigated in both discharges, in contrast with the standard weighted sum analysis that finds $f_{rad} = 0.77$ and 0.90 respectively. However, both results are within the uncertainty margin, and f_{rad} as low as $\sim 65\%$ is possible for 95709. Time-dependent toroidal peaking factors will be presented.

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