

Bayesian integrated estimation of tungsten impurity concentration distributions at WEST using soft X-ray and bolometer diagnostics

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Tungsten (W) has been chosen as the material for the ITER divertor and first wall. Tungsten impurities entering the plasma through plasma-wall interaction processes may cause significant radiative power loss and degrade the reactor performance. In a hydrogenic plasma with dominant W impurities at trace concentration ($c_W = n_W/n_e \ll 1$), the plasma emissivity filtered by a certain spectral response η can be expressed as $\varepsilon^\eta \approx n_e^2 [L_H^\eta(T_e) + c_W \cdot L_W^\eta(T_e)]$, where L_H^η and L_W^η are the filtered cooling factors of hydrogen (deuterium) and tungsten, respectively. This allows us to estimate W concentrations using measurements of plasma emissivity, n_e and T_e . Previous studies revealed that the W concentration reconstructed from soft X-ray (SXR) alone is uncertain at the plasma edge due to the weak SXR radiation [1]. Using the integrated data analysis (IDA) approach based on Bayesian probability theory, one can combine the data from SXR, bolometry, interferometry and ECE, jointly estimating the W concentration profiles and kinetic profiles (n_e and T_e), increasing the reliability of the inferred W concentration and ensuring consistency [2]. The joint posterior probability distribution of the profiles must be explored by a Markov chain Monte Carlo (MCMC) sampler. The difficulty of sampling from the high-dimensional and strongly correlated joint posterior distribution can be resolved by applying reparameterization. First results using synthetic data and experimental data from WEST indicate the strong potential of this method [3]. Indeed, after including bolometry data, the test on synthetic data yields very accurate W tungsten concentration estimates for both core and edge regions, as shown in figure 1.

References

- [1] Hao Wu et al. “Estimation of the Radial Tungsten Concentration Profiles from Soft X-ray Measurements at WEST with Bayesian Integrated Data Analysis”. In: *Journal of Fusion Energy* 43.1 (2024), pp. 1–13. DOI: 10.1140/epjp/s13360-021-01483-z.
- [2] R Fischer et al. “Integrated data analysis of profile diagnostics at ASDEX Upgrade”. In: *Fusion science and technology* 58.2 (2010), pp. 675–684. DOI: 10.13182/FST10-110.
- [3] Hao Wu et al. “Bayesian integrated estimation of two-dimensional tungsten concentration profiles at WEST using soft X-ray and bolometry diagnostics”. In: *Plasma Physics and Controlled Fusion* 67.8 (2025), p. 085001. DOI: 10.1088/1361-6587/adb00b.

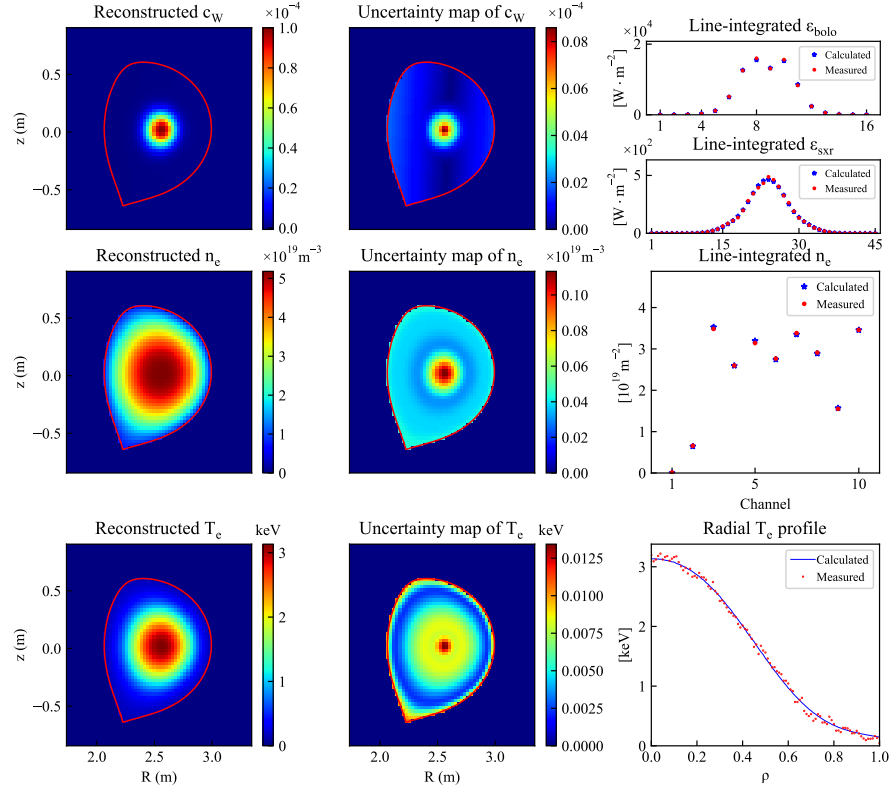


Figure 1: Profiles reconstructed from synthetic interferometry, ECE, SXR and bolometry data. Left column: reconstructed profiles given by posterior means. Middle column: uncertainty maps represented by the posterior standard deviations. Right column: comparison between the signals from the original synthetic ‘measurements’ and those calculated using the reconstructed profiles. Reproduced with permission from [3].