Using X-ray measurements to assess uncertainties in plasma temperature and impurity profiles in tokamaks

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In tokamaks, the local X-ray plasma emissivity results from the contribution of several plasma parameters, i.e. electron temperature, density and concentration of impurities in multiple ionization states. In particular, the impurity core concentration can be estimated from the emissivity in the soft X-ray (SXR) range 0.1 – 20 keV, while information about suprathermal electrons is obtained in the hard X-ray (HXR) range 20 keV – 200 keV [1]. Estimating tungsten (W) concentration is subject to uncertainties as it requires accurate knowledge of plasma temperature, magnetic equilibrium, atomic processes leading to its cooling factor and diagnostic spectral response [2]. When other plasma parameters are known, the W impurity density can be reconstructed in the core with the help of SXR tomographic tools [3], using:

$$n_W = \frac{\varepsilon^{\eta}_{\mathrm{SXR}} - \sum_{S\neq W} \varepsilon^{\eta}_{S}}{n_e . L^{\eta}_{W}(T_e)}, \qquad (1)$$

where $\varepsilon^{\eta}_{\mathrm{SXR}}$ denotes the reconstructed SXR emissivity, $\sum_{S\neq W} \varepsilon^{\eta}_{S}$ the contribution from the background plasma and other impurities, and L^{η}_{W} the SXR-filtered W cooling factor, assuming a weak dependency to density and local W transport $L^{\eta}_{W}(T_e, n_e, \vec{\Gamma}_W) \approx L^{\eta}_{W}(T_e)$. Nevertheless, in the case of a significant suprathermal electron fraction e.g. due to RF heating, electron temperature estimation from ECE measurements can become a challenging task [4].

Therefore, the goal of this contribution is to establish a methodology to assess the uncertainty in the core T_e and $c_W = n_W/n_e$ based on several X-ray measurements. The strategy is to define a grid of ($T_{e,0}$, $c_{W,0}$) candidates, keeping the same radial shape, and identify the ones having the highest consistency with multiple line-integrated measurements in different energy bands. The method is at first tested on well-known synthetic profiles in an arbitrary tokamak geometry [3] to study the capabilities of the approach. W line emission is estimated thanks to the Photon Emissivity Coefficients (PEC) provided by Open-ADAS [5]. A synthetic line-integrated SXR spectrum emitted by a plasma containing W impurities ($c_W = 10^{-4}$) is presented in Fig. 1, where three spectral regions are identified: 0 - 1 keV and 1 - 5 keV