

# **Novel methods for evaluating Thomson scattering data to improve the accuracy of the electron density and its error estimate**

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Laser Thomson scattering is employed in fusion experiments to determine the electron density and temperature from the measured spectrum of the scattered photons. However, the whole spectrum cannot be measured with sufficient accuracy for a single laser pulse. Instead, so-called polychromators are used. These split the full wavelength range into a number of channels and integrate the spectrum over those channels. The spectrum is then reconstructed from those discrete measurements. Due to noise (electronic and photon shot noise) there is an uncertainty in this reconstruction and, hence, in the density and temperature determined from it. In reality, however, variations between individual laser pulses or adjacent spatial points are often larger than the uncertainties arising from the reconstruction. This is especially true for the electron density. It is often challenging to identify the exact cause for such additional uncertainties and, consequently, to quantify a reliable estimate for the experimental error.

In the first experimental campaigns of Wendelstein 7-X it was found that misalignment of the laser beam was the dominant reason for uncertainties in the electron density. Besides mechanical improvements of the beam path, a novel calibration technique has been established, which accounts for any remaining alignment variations and substantially improves the profile quality. This technique may be crucial for larger fusion experiments like ITER, which necessarily have long beam paths. But the question remains, how error bars can be quantified reliably, possibly even accounting for unknown error sources. For this, the distribution of measured signal levels during the absolute Raman calibration (with constant conditions) has been determined. This distribution covers all fast changes to the overall sensitivity of the diagnostic (vibrations, detector gain, etc.) and in combination with the calibration uncertainties and the error due to the imperfect reconstruction of the spectrum, this distribution gives a realistic and experimentally accessible error estimate for the electron density. In this regard it was an interesting finding that for some polychromators the error distribution was not symmetric. For such a distribution, the mean value is different from the maximum of the distribution (modus). This implies that the calibration factor relating the intensity to the electron density, which is determined from the mean of the distribution, yields slightly incorrect density values for most of the measurements. This effect can be mitigated by using the empirical distribution as error estimate.