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Improved Uncertainty Modeling for the Helium Collisional-Radiative Model used for Line-Ratio Spectroscopy on Wendelstein 7-X

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Understanding the basic plasma parameters of temperature and density, as well as their gradients in the scrape-off layer (SOL), is a topic critical for providing information about the performance of a divertor concept. The stellarator Wendelstein 7-X features a novel resonant island divertor with an adjustable rotational transform of $\iota = 2\pi$ (5/6, ⋯, 5/4). In order to study the performance of this divertor concept, an active spectroscopy system on a thermal helium beam [1] was developed and installed on the device [2]. The system consists of four identical Czerny-Turner spectrometers imaging two stellarator-symmmetric upper and lower divertor modules, allowing for tomographic reconstruction of impurity radiation in the island divertor region. The helium beam diagnostic operates using the technique of line ratio spectroscopy, applying a collisional-radiative model (CRM) to relate the observed line radiation to the underlying plasma parameters [3]. Despite successful operation during previous experiments, there have been systematic disagreements observed between the helium beam and other edge diagnostics. In order to investigate the uncertainties of the helium beam diagnostic and the vulnerabilities of the underlying atomic data set, a complete Bayesian treatment has been undertaken with the Minerva Bayesian modeling framework [4]. First, it has been shown through a sensitivity study that the diagnostic method is robust against random measurement errors and systematic calibration errors on the scales achievable with the current diagnostic setup. From this, it is concluded that the majority of the uncertainty in the reconstructed temperature and density arises from systematic uncertainties in the underlying CRM rather than from measurement errors, and that a narrow subset of these processes is disproportionately responsible for plasma profile reconstruction uncertainties [5]. A new R-matrix data set for helium has been calculated and its differences from previous data sets will be discussed, as well as the implications on plasma parameter reconstructions. Finally, corrections for finite magnetic field effects are discussed and the relevant regimes for neglecting these effects are shown.

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Presenting Author

Erik Flom

Presenting Author Affiliation

UW-Madison / IPP-Greifswald

Presenting Author Gender

Male

Country

USA

Presenting Author Email Address

erflom@wisc.edu

Primary author: FLOM, Erik (UW-Madison)

Co-authors: Dr BARBUI, Tullio (PPPL); Prof. SCHMITZ, Oliver (UW-Madison); Dr HARRIS, Allison (Illinois State U.); Dr KOENIG, Ralf (IPP-Greifswald); Dr KWAK, Sehyun (IPP-Greifswald); Dr SVENSSON, Jakob (IPP-Greifswald); Prof. LOCH, Stuart (Auburn U.)

Presenter: FLOM, Erik (UW-Madison)

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