Comparing Particle Transport Modulation Study Methodology

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The relative contributions of transport and fueling can now be disentangled by using novel edge particle source diagnostics. High performance in fusion reactors is tied to overall density, often dependent on operating with a density pedestal. The shape of these pedestals has a strong influence on overall performance and is set by an interplay of particle transport and fueling by neutral particles from the edge and/or pellets. We expand on recently published results[1] by more explicitly highlighting the degree of improvement provided by forward modeling informed by edge particle source measurements over the previously typical analytical method[2]. The previous analytical method involves fitting density perturbations with sinusoidal functions to develop closed form expressions for the transport coefficients from the fitted amplitude and phase but is found to be highly dependent on perturbations with large relative amplitude, minimal noise, and an approximately sinusoidal response, even when modified to include particle source modulations. In the new method, particle transport coefficients are obtained in the pedestal region of DIII-D by utilizing calibrated source measurements in a time-dependent forward modeling framework with Bayesian inference to optimize a diffusion and convection profile against density profile measurements. This method allows for separation of diffusion and convection terms by exploring the evolution of the density profile through dynamic events such as gas puff modulation and is not strictly reliant on an approximately sinusoidal perturbation. Improvements in methodology are demonstrated by considering idealized synthetic data, then working up through progressively more complex scenarios towards experimental results. Thanks to these improvements in methodology, we have a better understanding of how to unravel the complicated transport dynamics of the pedestal region and optimize them for higher performance.

[1] A.M. Rosenthal et al 2024 Nucl. Fusion 64 036006

[2] H. Takenaga et al 1998 Plasma Phys. Control. Fusion 40 183

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