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Real-Time Detachment Forecaster: Decoding X-Point Radiation Oscillations in Impurity-Seeded Plasmas

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Impurity seeding plays a pivotal role in achieving plasma detachment by reducing heat and particle fluxes to divertor targets, yet requires precise real-time control of seeding rates. Current diagnostic limitations and manual adjustments impede this process. For instance, the credibility of Langmuir probes becomes suspect under the heating of reactor level [#1]. Additionally, line-integrated measurements of the radiation spectrum can only yield rough and time-lagged two-dimensional radiation distributions [#2].

Consequently, a deep learning model has been developed for monitoring detachment in EAST, enabling instantaneous prediction of the electron temperature near divertor strike points. The model avoids reliance on Langmuir probes by utilizing photodiode radiation data and accommodating diverse operational conditions [#3].

Rigorous analysis has confirmed that the detachment state is primarily determined by the neutral beam injection (NBI) power, plasma current, line-averaged density, and impurity seeding rate [#4] (see Figure 1). Notably, it turns out that NBI synergizes with radio-frequency heating, broadening heat flux profiles and thereby facilitating plasma detachment. Moreover, the effect of impurity seeding remains consistent across different toroidal seeding locations [#3].

Crucially, the model demonstrates self-consistent predictions across nitrogen, neon, and argon seeding scenarios, despite being trained solely on nitrogen data. (see Figure 2). This consistency further validates the model' s applicability across diverse impurity seeding scenarios. The relative efficiencies among different impurity species are compared with the theoretical values in reference [#5], which rectifies the flaws of 1D models. This fresh perspective will advance the understanding of detachment control.

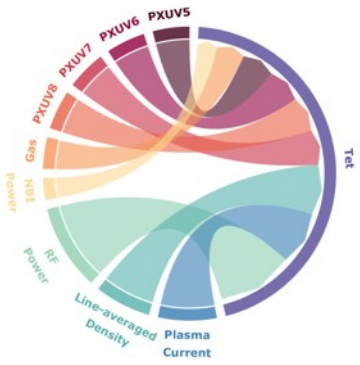

Figure 1: Figure 1. Cross-Correlations Between Input Variables and the Output

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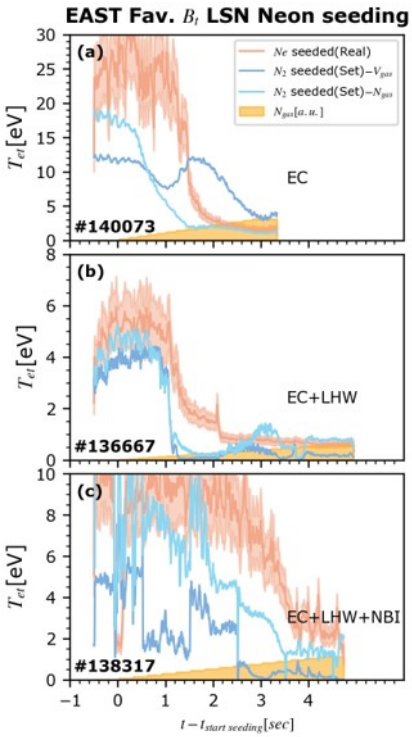

Figure 2: Figure 2. Validation of the Underlying Physics of the Model with Neon Seeding Scenarios

Figure 2. Validation of the Underlying Physics of the Model with Neon Seeding Scenarios

References

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