Contribution ID: **36** Type: **Oral**

Core-edge Integrated Simulations of Ne-seeded JET-ITER Baseline Scenarios

Friday 31 October 2025 10:05 (20 minutes)

The Ne-seeded JET-ITER baseline is a robust scenario that can achieve simultaneous partial divertor detachment and high-confinement (H_{98} > 0.85-1.0) with small or no ELMs at JET [1, 2, 3]. In these highly fuelled, high-triangularity scenarios with vertical target divertor configuration, Ne-seeding opens access to reduced pedestal top electron density, $n_{\mathrm{e,PED}}$, with low pedestal collisionality and improved overall confinement, primarily driven by pedestal pressure increase relative to the unseeded conditions. Simultaneously, ELMs are reduced in size and eventually disappear with increasing neon content. This contribution reviews the recent activities in core-edge integrated simulations and analysis of these scenarios with standalone SOL transport simulations with EDGE2D-EIRENE, SOLEDGE3X, and SOLPS-ITER supporting integrated JINTRAC-COCONUT analysis. The chosen approach is such that SOLEDGE3X and SOLPS-ITER pursue detailed boundary model validation, while EDGE2D-EIRENE is used to bridge the integration gap to the JINTRAC-COCONUT simulations. A key goal for the core-edge integrated simulation workflow is to provide physics insight to the main drivers responsible for the $n_{\mathrm{e,PED}}$ reduction at JET as well as to address how these drivers impact the overall divertor design and extrapolation of exhaust-integrated scenarios to the scale of reactors.

The $n_{\mathrm{e,PED}}$ reduction is hypothesized to be driven by a combination of (1) increase in pedestal particle transport, (2) reduction of ionization sources inside the pedestal, $S_{\mathrm{IZ,PED}}$, and (3) reduction of separatrix electron density, $n_{\mathrm{e,SEP}}$, due to the onset of detachment and starvation of the divertor plasma from power to ionize neutrals. While gyrokinetic simulations of the pedestal plasmas have not yet identified a turbulent flux compatible with the observed reduction of $n_{\mathrm{e,PED}}$, the SOL simulations indicate the presence of the other two mechanisms (2, 3) with their magnitude depending on user-assumptions of the uncertain code parameters. For example, EDGE2D-EIRENE simulations predict a ~x4 reduction of $S_{\mathrm{IZ,PED}}$ and about a 25% reduction of $n_{\mathrm{e,SEP}}$ with Ne-seeding. These observations are associated with a x2-3 reduction in the neutral pressure in the vacuum region surrounding the plasma in the simulations, consistent with experimentally observed ~x3 reduction in the horizontally line-integrated D_α-light at the mid-plane level, including sub-traction of reflections according to the method detailed in [4]. Both results give an indication that reduction in $S_{\mathrm{IZ,PED}}$ is likely to play a role in the $n_{\mathrm{e,PED}}$ reduction. The exact balance between the three drivers can only be narrowed by the detailed validation effort, including extended grids and drifts with SOLEDGE3X and SOLPS-ITER. The boundary simulations are now used to guide the JINTRAC-COCONUT analysis for a calibrated core-edge simulation effort to proceed towards an integrated analysis of the exhaust-integrated pedestal at Ne-seeded JET-ITER baseline.

[1] C. Giroud, et al. IAEA-FEC 2025.
[2] C. Giroud, et al. PSI 2024.
[3] C. Giroud, et al. IAEA-FEC 2021.
[4] L. Horvath, et al. Plasma Phys. Control. Fusion 65 (2023) 044003.

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Session Classification: Towards Integrated Scenarios for Exhaust

Track Classification: Towards Integrated Scenarios for Exhaust