

Seminar

Institute for Plasma Research

Title: Stochastic approach to three-dimensional Scrape-off layer transport characteristics in magnetically confined plasmas

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Date: 10th December 2025 (Wednesday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

Link: <https://bharatvc.nic.in/join/7958694699>
(Conference ID: 7958694699; Password: 452782)

Abstract

Understanding plasma transport and wall interactions in magnetically confined fusion devices is essential for ensuring reliable operation and maintaining component integrity. This work presents a comprehensive investigation of scrape-off layer plasma behavior, intrinsic flow generation, and first-wall heat-load characteristics using the 3D plasma-neutral transport code EMC3-EIRENE. The work spans both medium-size tokamak experiments and reactor-scale configurations, providing physics insights relevant to present devices and future fusion reactors.

The first part establishes a baseline analysis of inboard-limited Aditya-U plasmas. This work builds upon earlier Aditya configuration studies for the ring limiter and the 3-block outboard limiter [1,2]. Extending this foundation, the present work performs the first detailed 3D simulations of the Aditya-U inboard continuous belt limiter, a geometry that introduces strong high-field-side recycling. Coupled plasma-neutral simulations recover the intrinsic rotation reversal observed in recent Aditya-U experiments, where toroidal flows change sign with density variation [3]. The simulations reproduce the development of mutually counter-propagating toroidal flows in the SOL at higher density and input power conditions [4]. This behaviour is shown to originate from the poloidal density variations produced by intense inboard recycling on the belt limiter, which drive residual-stress-related momentum transport. Comparison with Doppler-shifted impurity rotation measurements confirms the qualitative agreement, highlighting the role of residual stress and poloidally asymmetric recycling in setting the intrinsic rotation structure in Aditya-U.

The second part is a continuation of the intrinsic rotation investigation, performed specifically for the edge toroidal rotation recently measured in Aditya-U. This work compares Aditya-U experiments that reported edge toroidal rotation decreasing with increasing edge density [5] with dedicated EMC3-EIRENE simulations [6]. The analysis shows that SOL pressure gradients maintained by the inboard limiter are the primary source of the background toroidal rotation field. This work clarifies how the combined action of SOL pressure gradients and the evolving E_r governs the conditions under which intrinsic rotation is experimentally detectable in limiter plasmas.

The later part of the thesis focuses on ITER, where the early limiter start-up phase at $I_p = 2$ MA is investigated. EMC3-EIRENE is used to model the plasma interaction with the 3D-shaped inboard First Wall Panels. The

simulations quantify the resulting heat-load distributions on the FWPs during the current ramp-up. These results are tried to compared against equivalent SOLPS-ITER simulations, establishing confidence in the predictive capability of the 3D model. Comparisons with SMITER-based field-line tracing further reveal the significance of cross-field transport and plasma-neutral coupling during start-up.

References:

- [1] B.P. Sahoo et al Nucl. Fusion 55 (2015) 063042
 - [2] Sahoo et al. Phys. Plasmas 24, 082505 (2017)
 - [3] Shukla G. et al 2019 Nucl. Fusion 59 106049
 - [4] Arzoo Malwal et al 2024 Nucl. Fusion 64 096024
 - [5] Ankit Kumar et al 2024 Nucl. Fusion 64 086019
 - [6] Arzoo Malwal et al Nucl. Fusion 65 (2025) 116011
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