Modelling Impurity-Seeded Plasmas at JET: Core, Edge, and Pedestal

M. Marin[1], C. Giroud[2], S. Wiesen[3], V. Parail[2], F. Auriemma[4], F. Eriksson[2], D. Fajardo[5], L. Frassinetti[6], L. Garzotti[2], S. Gabriellini[2], Q. Hu[7], P. Innocente[4], I. Ivanova-Stanik[8], A. J¨arvinen[9], D. Kos[2], K. D. Lawson[2], C. Leoni[10], P. Mantica[7], A. Mariani[11], S. Menmuir[2], D. Moulton[2], O. Pan[5], I. Predebon[4], S. Saarelma[2], V. K. Zotta[10] and JET Contributors* and the EUROfusion Tokamak Exploitation Team[+]

[1]Swiss Plasma Center, EPFL, Lausanne, Switzerland, [2]UK Atomic Energy Authority, Culham Science Centre, United Kingdom, [3]DIFFER, Eindhoven, Netherlands, [4]Consorzio RFX, Padova, Italy, [5]Max Planck Institute for Plasma Physics, Garching, Germany, [6]KTH Royal Institute of Technology, Stockholm, Sweden, [7]Istituto per la Scienza e Tecnologia dei Plasmi, CNR, Milano, Italy, [8]Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland, [9]VTT Technical Research Centre of Finland, Finland, [10]Sapienza University of Rome, Italy, [11]Institute for Plasma Science and Technology, Milano, Italy, see Maggi et al 2024 for JET collaborators, see Joffrin et al 2024 for the EUROfusion Tokamak Exploitation Team.

Impurity seeding will be essential to protect the divertor and control power exhaust in future fusion reactors. Understanding impurity effects in current experiments is key to planning exhaust strategies in future machines. While core radiation and dilution are expected to degrade performance, experiments have shown instances of improved energy confinement following seeding. This talk aims to explain this effect starting from a high-power, high-triangularity neon seeding scan at JET, which showed enhanced confinement [1]. A comprehensive view requires careful review of past modelling of seeded scenarios, particularly at JET. The observed confinement and neutron rate increases result from complex interactions between edge, core, and pedestal—though these have largely been studied separately. In the core, increases in temperature and density peaking were linked to ITG mode dilution, in both C-wall [2,3] and W-wall discharges using TGLF [4] and QuaLiKiz [5,6]. Edge modelling with SOLPS and EDGE2D qualitatively reproduced key trends from Neon and Nitrogen seeding: ionization front position, target heat flux reduction [7,8], and separatrix conditions [9]. The pedestal remains the least understood, due to the absence of a predictive model and the intricate role of transport and MHD. Ongoing gyrokinetic and MHD studies aim to reach a qualitative understanding of pedestal changes post-seeding. The talk will conclude with first attempts at integrating core, edge, and pedestal to enable further modelling across a wider range of experiments [10,11].

References

[1] C. Giroud, D. King, L. Frassinetti et al. Marseille, 26th PSI, 12-17 May, (2024)
[2] M.Z. Tokar, H. Nordman, J. Weiland et al., Plasma Phys. Control. Fusion 44, 1903 (2002)
[3] S. Moradi, C. Bourdelle, M.Z. Tokar et al., Plasma Phys. Control. Fusion 54, 015004 (2012)
[4] S. Glöggler, M. Wischmeier, E. Fable et al., Nucl. Fusion 59, 126031 (2019)
[5] M. Marin, J. Citrin, C. Giroud et al., Nucl. Fusion 63, 016019 (2023)
[6] S. Gabriellini, L. Garzotti, V.K. Zotta et al. Nucl. Fusion 63, 086025 (2023)
[7] A.E. Jaervinen S. Brezinsek, C. Giroud et al. Plasma Phys. Control. Fusion 58, 045011 (2016)
[8] A.E. Jaervinen, C. Giroud, M. Groth et al., Nucl. Fusion 56, 046012 (2016)
[9] E. Kaveeva, V. Rozhansky, I. Veselova et al. Nucl. Materials and energy 28 101030 (2021)
[10] C. Giroud, S. Brezinsek, R.A Pitts et al. Virtually, 28th IAEA-FEC (2021)
[11] I.S. Carvalho, C. Giroud, D.B. King et al. Salamanca, 50th EPS, 8-12 July (2024)