CONFINEMENT MODELLING OF ENHANCED PLASMA PERFORMANCE AFTER MULTIPLE PELLET INJECTIONS IN THE TJ-II STELLARATOR

[1]V. TRIBALDOS, [2]I. GARCÍA-CORTÉS, [2]K.J. McCARTHY, [1]J.M. REYNOLDS-BARREDO, [2]D. MEDINA-ROQUE, [2]A. BACIERO, [3]O.O. CHMYGA, [2]T. ESTRADA, [3]O.S. KOZACHOK, [2]D. LÓPEZ-BRUNA, [2]F. MEDINA, [2]B. van MILLIGEN, [2]J.L. de PABLOS, [2]N. PANADERO, [2]I. PASTOR, [2]J. DE LA RIVA and [2]TJ-II TEAM

[1] Universidad Carlos III de Madrid, Leganés, Madrid, Spain
[2] Laboratorio Nacional de Fusión, Ciemat, Madrid, Spain
[3] Institute of Plasma Physics, NSC KIPT, Kharkiv, Ukraine

E-mail: Victor.Tribaldos@uc3m.es

Abstract: Recent experiments employing multi-pellet injection in NBI-heated plasmas in the TJ-II stellarator have achieved record energy confinement times [1,2], surpassing predictions derived from the ISS04 scaling law [3]. This enhanced confinement regime is characterized by the highest ion temperatures yet measured and record densities. While these observed profile modifications are suggestive of a potential neoclassical transport mechanism, due to its strong collisionality dependence, simultaneous measurements of reduced density and electrostatic potential fluctuations in the density gradient region point to a non-negligible contribution from turbulent transport to the overall enhanced confinement. Here it is shown that the increased ion temperature due to the multi-pellet injection reduces neoclassical diffusion from the Pfirsch-Schlüter to the *Plateau* collisionality regimes and partly explains the enhanced plasma performance in these NBI-heated TJ-II conditions.

1. INTRODUCTION

For the last few years pellet injection experiments in TJ-II have expanded beyond previous works on ablation, deposition, and fueling efficiency [4-6] to study the effect of multiple cryogenic hydrogen pellet injections, into NBI-heated plasmas, on enhanced performance scenarios. An extensive comparison shows a significant plasma triple product improvement compared to other plasma fueling methods with record ion temperatures and diamagnetic energy confinement times exceeding ISS04 predictions. The plasmas obtained with multiple pellet injections are found to have sustained record central densities, ion temperatures and normalized β. Furthermore, broader density profiles along with the somewhat more negative radial electric field measurements point to improved ion confinement thereby suggesting a neoclassical connection. However, the strong reduction of density and electrostatic potential fluctuation in the outer plasma region does not rule out a reduced turbulent channel [7].

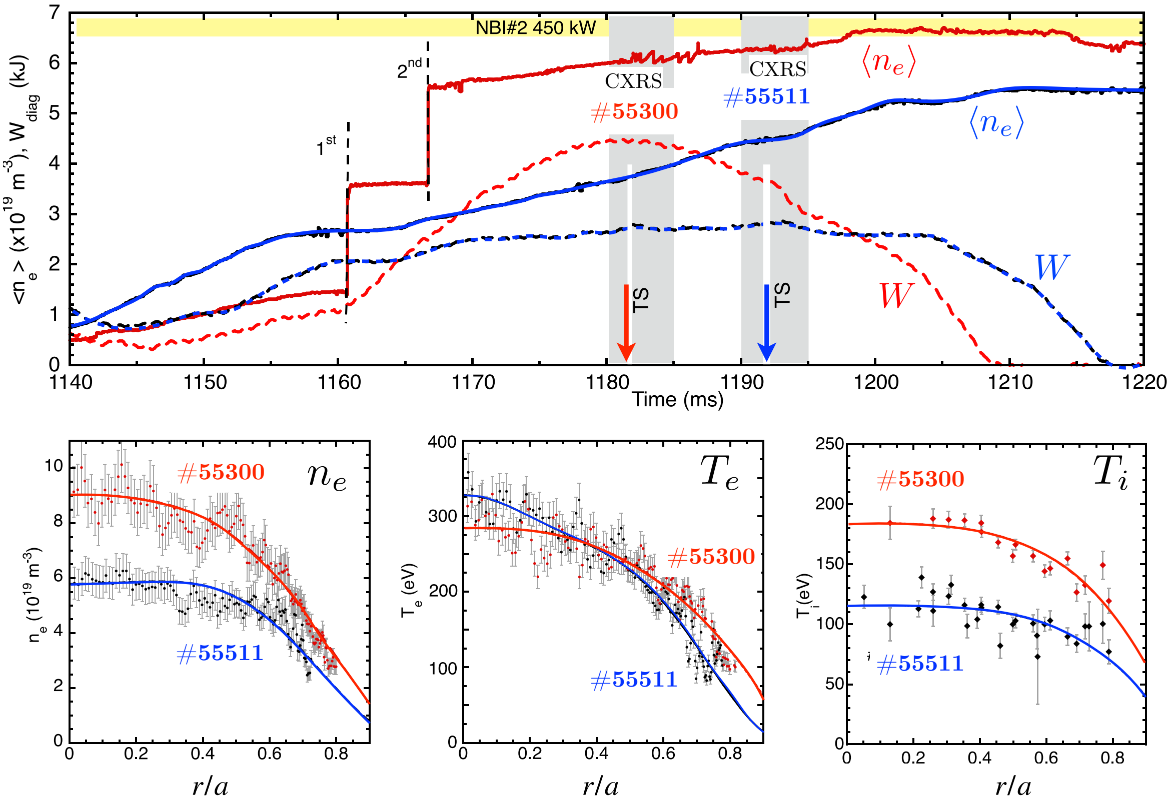

Figure 1: Top: Time traces of line-averaged density (solid) and stored diamagnetic energy (dash) for discharges with #55300 and without #55511 pellets. Bottom: density, electron and ion temperature profiles for the same discharges. Figures 4 and 5 from McCarthy K.J. *et al* in [2].

2. NEOCLASSICAL SIMULATIONS

To clarify the impact of neoclassical transport in this new confinement regime, simulations with and without pellet injection and a comparison with the energy confinement times obtained from the ISS04 and experimental power balance analysis are done using the monoenergetic treatment procedure from [8] with a combination of MOCA [9], for the radial diffusion, and DKES [10], for the bootstrap and momentum correction, codes.

The effect of the pellets is to increase not only the density, which is expected, but contrary to the usual behavior, to significantly increase the ion temperature, while keeping the electron temperature unaltered, see Figure 1. Neoclassical simulations show a reduction of the collisionality from $\upsilon^* = 0.8$ in #55511 to $\upsilon^* = 0.3$ in #55300, their profiles being quite flat, which changes the collisionality regime from the Pfirsch-Schlüter in #55511 to the *Plateau* in #55300, resulting in a decrease of the diffusion coefficient.

Shot	W_{diag} [kJ]	$\tau_{\mathrm{E}}^{\mathrm{PB}}$ [ms]	$\tau_{\mathrm{E}}^{\mathrm{ISS04}}$ [ms]	$\tau_{\mathrm{E}}^{\mathrm{NC}}$ [ms]	P^{NC} [kW]	I_{b} [kA]
#55511	2.2	8.5	10	21	55	0.6
#55300	4.4	14	12.5	18	120	1.1

Table 1: Results of neoclassical (NC) simulations with #55300 and without #55511 pellet injection compared with ISS04 and power balance (PB) analysis.

The explanation why neoclassical calculations yield a lower energy confinement time for #55300 than for #55511, see Table 1, is that the decrease in the diffusion coefficient is partly offset by the increase in both the density and temperature gradients in the calculation of the particle and heat fluxes. The small changes predicted for the radial electric field are consistent with the mild dependence for these collisionality regimes below radial electric field resonance values.

3. CONCLUSSIONS

An enhanced confinement regime is obtained in NBI-heated plasmas at TJ-II induced by multi-pellet injection. This can be clearly seen by the doubling of the diamagnetic energy content from 2.2 kJ in discharge #55511 to 4.4 kJ in discharge #55300 with the same heating power $P_{NBI} = 320$ kW. Compared to this injected power, the neoclassical integrated heat fluxes, see Table 1, can only account for 55 kW of #55511 and 120 kW of #55300, clearly indicating that other transport mechanisms are involved in supporting the enhanced confinement regime [11]. A systematic comparison between neoclassical and ASTRA [12] simulations is underway to quantify these transport channels.

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