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INTRODUCTION

In the tokamak JET it is observed a systematic discrepancy when comparing the neutron yields as measured by KN1 diagnostic (fission chamber) with the results of codes assuming no fast particle transport beyond collisional diffusion (for example PENCIL, CHEAP, Nubeam, ASCOT). As data values from simulations are typically higher than the experimental ones, this is called 'neutron deficit' [1]. On the other hand, recent studies suggest that one of the mechanism through which the NTM island degrades tokamak performances is the expulsion of part of the fast ions from the core of the plasma, thus reducing the rate of nuclear reactions, and ultimately producing a neutron yield lower than expected. Fast ion dynamics simulations with the Monte Carlo code ASCOT [2, and references therein] modified to account for the magnetic island presence, confirm qualitatively this pattern when compared with tokamak data [3].

In this work we study how the comparison between experimental and simulated neutron yields changes when the island effects are implemented into a transport code. The suite of transport codes JINTRAC has been specifically modified and the island parameters are determined from experimental data.

1. THE MODEL AND THE METHOD

JINTRAC [2] is a system of 25 interfaced Tokamak-physics codes for the integrated simulation of all phases of a Tokamak scenario. In particular, in the core, transport equations for the flux- surface averaged fields of two fluid plasmas are solved using the transport code JETTO coupled to the impurity transport code SANCO. Neutral beam injection (NBI) is modelled through the Monte Carlo orbit following code ASCOT.

The presence of an island in a discharge is determined examining the spectrogram of tangential pickup coils signals, its poloidal and toroidal periodicity (m,n) from their Fourier analysis, its radial position from ECE correlation. Island widths are to be considered purely indicative as their evaluation is based upon a scaling whose parameters are not necessarily optimised for the chosen pulses. A parametric scan around these values has being performed and the values leading to a simulated electron temperature profile that better matches the experimental one have been chosen.

JETTO with Bohm/Gyro-Bohm model is used in a predictive way, in order to assess the correctness of the models we are implementing. In this code the island effect is implemented by multiplying the transport coefficients by a factor 50×10^4 in a gaussian profile centred on the island position. The position is set providing the corresponding value of the safety factor q and the width by providing the sigma of the Gaussian. In ASCOT the island is implemented as a perturbation to the vector potential, periodic (m,n) in poloidal and toroidal direction. The radial position is again fixed via q and the width is provided setting the width of a profile in the poloidal flux coordinate ψ [3].

Initial temperature and density profiles are read from experimental data, with Ti set equal to Te. The equilibrium reconstruction (and consequently the q profile) is calculated by EFIT or from EFIT reconstruction constrained by polarimetry, MSE and pressure data, to ensure the correct positioning of the island inside the codes (EFTM).

The simulations are run for a time during which the island and other parameters (plasma current, NBI power) can be considered constant (typically 1s). A JETTO/ASCOT run requires typically around 10 hours on a Linux cluster using 64 processors.

2. SELECTION OF SHOTS AND CHARACTERISATION OF THEIR MHD ACTIVITY

We compare a pulse with neutron deficit (77269) and one without (84862). Literature [1] and ongoing work by the authors report large neutron deficit in baseline discharges and good agreement between measured and simulated neutron yields in hybrid ones. Coherently, JET Pulse Number: 77269 is a baseline JET-C pulse with a (3,2) island at 17s, 15cm wide. The equilibrium is calculated by EFIT, the initial profile for Zeff is read from experimental data. JET Pulse Number: 84682 is a hybrid ILW pulse with many MHD modes present during the discharge ((1,1), (5,4), (4,3), (3,2)). In the time window considered, the most important is a (4,3) at 6s with a width of 12cm. The equilibrium is calculated by EFTM, the initial value of Zeff is set uniformly equal to 1.3.

3. RESULTS

To assess the predictive capability of the simulations we compare the calculated Te and Ne profiles at the end of the simulation with the experimental ones (Figure 1). We see that the runs with island better match the experimental data. JET Pulse Number: 84682 is a ILW pulse and therefore results are to be considered preliminary, as the Tungsten dynamics has not yet been considered. Moreover it might benefit of a description with two or more islands of different position and periodicity – as the MHD analysis would suggest. Next, we compare the results of the simulations with the experimental neutron yield as provided by a fission chamber (Figure 2).

We see that in JET Pulse Number: 77269 the neutron deficit is reduced by the implementation of the island in the two codes. Moreover adding the island to JETTO is more effective than adding it to ASCOT. Coherently, in JET Pulse Number: 84682 we observe that neutron deficit is avoided only if the island is implemented and that the effect is much more visible in JETTO code results than in the ASCOT ones.

This happens because the effect of the island in JETTO is essentially to flatten electron density and temperature profiles in the interested zone, while in ASCOT it is to push fast ions toward a more external zone, where they find lower temperature and density, thus reducing their probability of producing nuclear reactions before being slowed down. In Figure 3 we see the reduction of the core fusion rate, the redistribution of the beam ion density and a reversal of the JxB torque, indicating a net velocity toward the edge. The effect of decreasing temperature and density in the core is apparently sufficient to decrease the rate of nuclear reactions even if no island related modification is implemented in fast ion trajectories calculation. Moreover, the effect in ASCOT is likely to be sensitive to the temperature and density gradients in the island location. In JET Pulse Number:

77269 the fast ion density has a steep gradient between rho = 0.3 and rho = 0.5 that is flattened by the island. On the other hand, in JET Pulse Number: 84682 the fast ion density has no step gradient region and is thus virtually unaffected by the island.

4. SUMMARY AND FUTURE WORKS

In a JETTO/ASCOT simulation of discharges with MHD activity, accounting for the presence of an island allows for better matching temperature and density experimental profiles.

In a pulse with neutron deficit, taking into account the island effects reduces the deficit itself. In a pulse without neutron deficit, withdrawing the island effects from the codes causes a deficit. These effects are more important in results from JETTO code than in ones from ASCOT.

The differences between the two kinds of pulses that are relevant for this phenomenon must still be investigated. This could benefit from a study of neutron distributions inside the plasma via an array of neutron cameras provided with horizontal and vertical lines of sight (KN3). Moreover, a better estimate of island width from experimental results would allow for simulations more relevant for actual discharges.

ACKNOWLEDGEMENTS

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REFERENCES

[1]. Y. Baranov, et al, Plasma Physics and Controlled Fusion, **51**, 044004 (2009)
[2]. M. Romanelli, et al, Plasma and Fusion Research, **9**, 34030231 (2014)
[3]. E. Hirvijoki, et al, Computer Physics Communications, **183**, 2589 (2012).

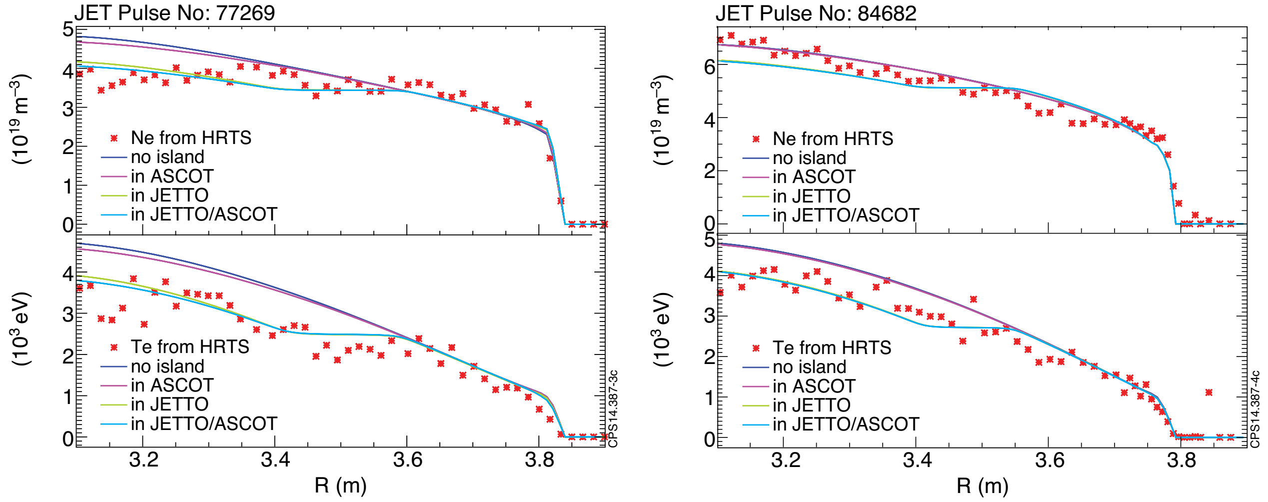

Figure 1: Electron Density and Temperature profiles after ~ 1s simulation.

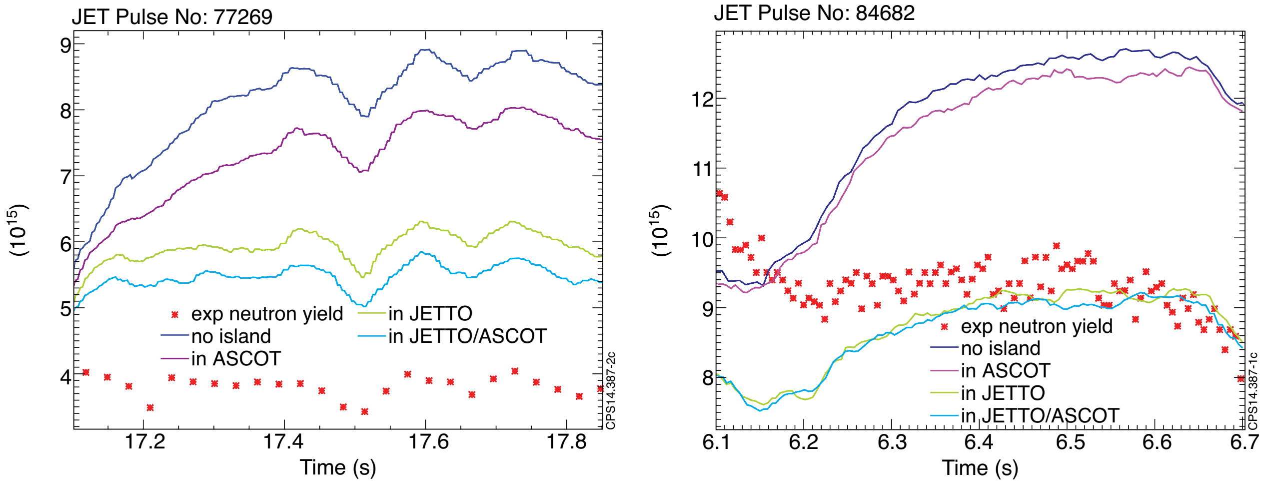

Figure 2: Time evolution of neutron yields.

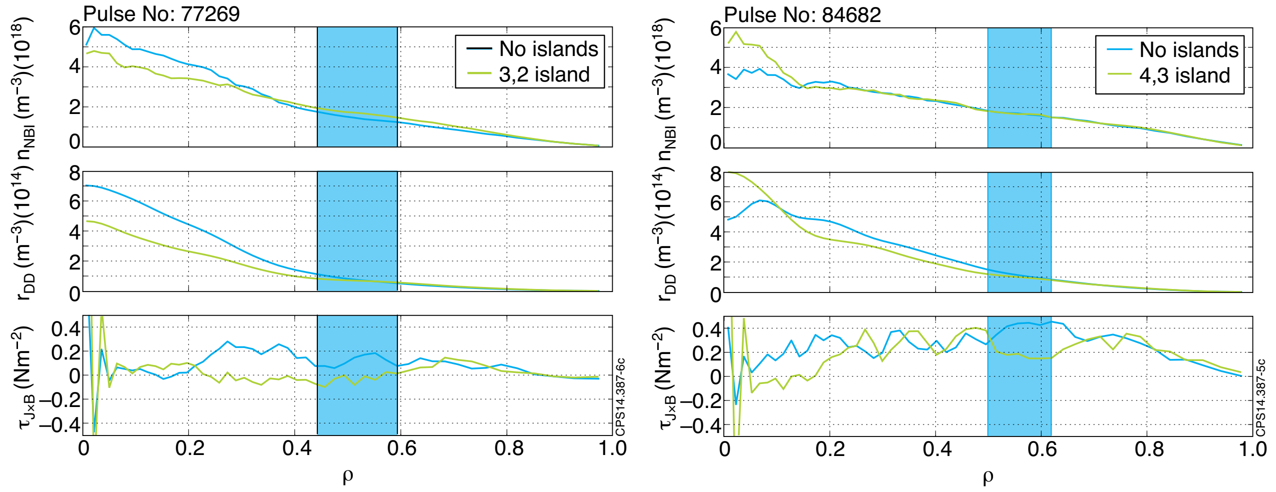

Figure 3: Profiles of beam ion density, fusion rate and JxB torque. The turquoise band indicates the island position.