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Impurity ion rotation and temperature behaviour in the TJ-II stellarator as a function of injected power and magnetic configuration

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Introduction. The TJ-II [1] is a low magnetic shear stellarator of the Heliac type with an average major radius of 1.5 m and an average minor radius of ≤ 0.22 m. Plasma is created and heated using two independent gyrotrons tuned to 2nd harmonic at 53.2 GHz that perpendicularly inject up to 0.6 MW of ECR power. We have performed C V poloidal rotation and temperature studies, while varying the total ECR injected power and scanning the magnetic configuration, using passive emission spectroscopy. The experimental system used in this work, the data reduction procedure and the method to extract local information from chord-averaged data are reported in detail in Ref. [2]. Despite the limitations inherent to passive emission spectroscopy in plasmas in the keV range, the scarcity of this type of data for ECRH stellarators justifies our present effort. In comparison with the few similar studies made in ECRH stellarators [3] and [4], this present one is performed with a multichannel (eight channels) system and covers the different operational regimes of TJ-II. The principal long-term aim of this work is to determine if Doppler studies can shed some light on the mechanisms involved in the degradation of plasma confinement with power and on the relationship between rotation and confinement.

ECR power scan. Several scans of injected power have been performed on the TJ-II stellarator operated in the standard configuration 100_40_63 and with either He or H_2 as the

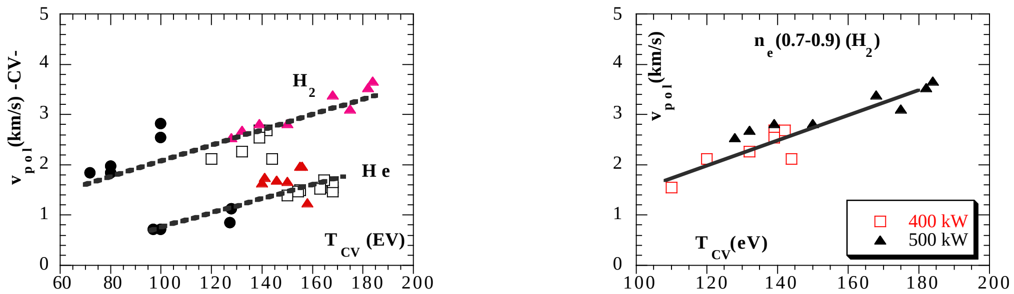


Fig. 1. Plot of C V poloidal rotation versus ion temperature (both chord-averaged): a) for a set of discharges either in H_2 and He and for different injected power and densities; b) for a more selected set of discharges in H_2.

working gas. In Fig. 1, we plot chord-averaged data showing C V poloidal rotation versus its temperature for a range of injected power values and for discharges in both gases. We observe a good linear relationship between both parameters while, in general, the C V rotation velocity is higher in H_2 than in He, although it could be merely a mass effect. The measurements for 500 kW discharges (triangles) correspond to the highest temperature and rotation values in H_2, but not in He. We believe that this is due to the difficulty of density control with increasing power in He discharges and correspondingly most of these discharges are in the highest density range (0.7 to 1.1). We must remark that these are chord-averaged data which were obtained by integrating the impurity line radiation along the plasma plateau in order to obtain good photon statistics. Here, only discharges with line averaged densities varying between 0.5 and 1 (10^{19} m^{-3}) are plotted.

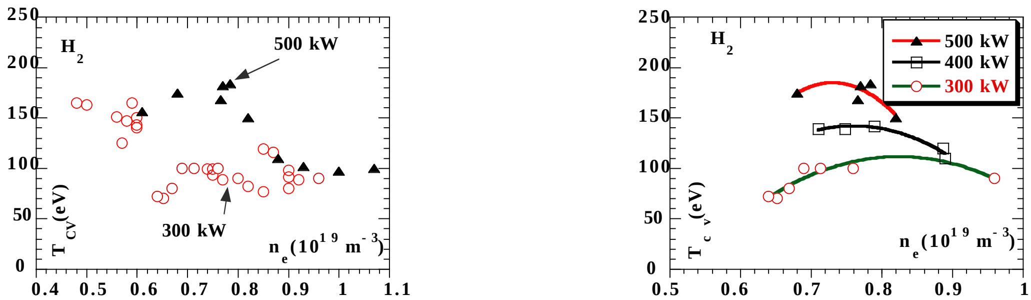
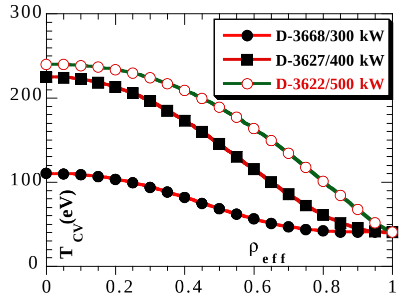


Fig. 2. Plot of C V chord-averaged temperature in H_2 versus line-averaged density; a) for several scans and for two different ECR powers; b) for selected scans and three different powers.

In order to highlight the influence of density on scans performed in TJ-II, we depict the behaviour of the maximum chord-averaged C V temperature obtained as a function of density in Fig. 2. In Fig. 2a, we grouped several scans made in H_2 at two injected powers, while in Fig. 2b we show a power scan performed in a single day with three injected powers. These plots emphasise that while the influence of power appears to be clear at intermediate densities it is not necessarily so over the entire density range.

Using the model described in Ref. [2], we have performed a detailed analysis of profiles from three discharges having a density of ~0.7x10^{19} m^{-3} but created with different levels of injected power. The aim was to study local changes in impurity temperature and rotation as a function of injected power. The local profiles deduced from this analysis are plotted in Fig. 3 where a clear rise is observed in impurity temperature as the ECR power is increased from 300 kW to 500 kW. A similar increase, accompanied by a change in sign in the outer parts of the plasma, is observed in poloidal rotation. Positive rotation corresponds to a positive radial electric field, therefore the plasma periphery becomes less negative and even positive as the injected power is raised. Although we have as yet performed a similar analysis for other densities, we believe that the observed behaviour with power may depend on the density. However, it may be difficult to achieve discharges with the required densities in TJ-II with this range of injected power.



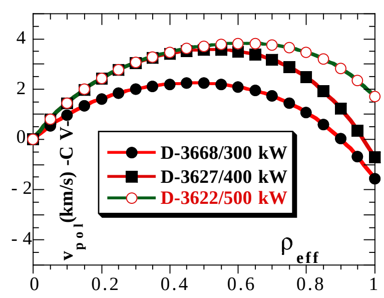
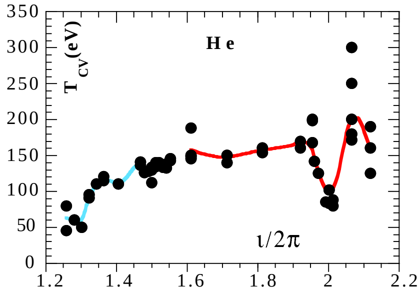
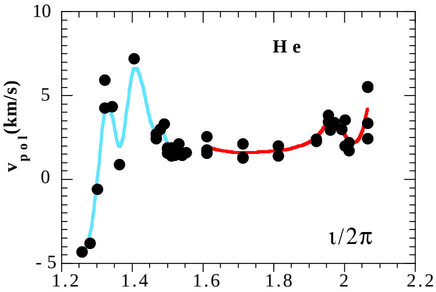


Fig. 3. Plot of local profiles deduced from chord integrated data by means of a local model, in a power scan performed at about 0.7x10^{19} m^{-3}; a) C V impurity temperature, and b) C V poloidal rotation.

Although a more complete analysis is needed before firm conclusions can be made, some general comments can be advanced from our data. Firstly, the impurity temperature changes significantly with injected power for similar densities. This is difficult to explain by the small changes observed in TJ-II electron temperature; their values appear to be higher than preliminary proton temperatures measured by a charge-exchange neutral spectrometer, which suggests that some anomalous effect may be influencing impurity temperature data. Secondly, the clear global correlation between temperature and poloidal rotation in the chord-averaged data of Fig. 1 suggests that the same mechanism might be responsible for causing effects in temperature or anomalous line broadening and rotation.

Magnetic configuration scan. We have recorded data while changing the TJ-II magnetic configuration and using He as the working gas. For this, the central iota value was varied from about 1.2 to beyond 2, the shear profile is quite flat as corresponds to a low shear stellarator. Maximum chord-averaged CV temperature and poloidal rotation data are plotted in Fig. 4 as a function of the central iota value. The most remarkable finding to emerge from this global plot is that we observe the lowest impurity temperature value at the lowest rotational transform and that in this range the shell, where C V emission peaks, rotates in the





negative direction.

Fig. 4. Results of the scan of magnetic configurations; a) A plot of maximum C V chord-averaged temperatures versus central iota value; b) A similar plot for C V poloidal rotation.

Conclusions. A systematic empirical study of impurity temperature and poloidal rotation has been performed in the TJ-II stellarator. We expect that this first global data set will help to address a deeper and more directed work in connection with theoretical studies to enable one to elucidate some issues related to ECRH physics. The availability of HIBP data and proton temperature profiles in the near future may contribute to a better understanding of these data.

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