Simulation of perturbative experiments in TJ-IU Torsatron

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INTRODUCTION

TJ-IU Torsatron (l=1, m=6, R=0.6 m, <a> = 0.1 m, ECRH heated at 37.5 GHz, 2nd harmonic) has been in operation at CIEMAT until 1997[1]. In previous work[2], TJ-IU plasmas have been characterised by atomic beam techniques as far as an inner radius of ρ=0.6 (ρ=r/a). A newly developed supersonic He beam and a thermal Li beam have been used for the determination of the electron temperature (He beam) and electron density (He and Li beams). Good agreement between both type of diagnostics was observed, in spite of the different assumptions made for the reconstruction of the profiles from the raw data. Steady state profiles at several electron densities ($<n_e>=2\text{-}6 \times 10^{18}$ m^{-3}), heating powers (P=90-200 kW), and magnetic configurations were obtained.

Transport analysis were performed using these experimental results and the central electron temperature measured with ECE. Once the confinement properties were found, simulations were performed for perturbative experiments, namely, gyrotron switch-off and Ar puffing.

CONFINEMENT PROPERTIES

The energy confinement time, τ_E, obtained using magnetic diagnostics ranges from 0.3 to 0.4 ms[1], depending on plasma characteristics. The energy confinement times obtained using several scaling laws are, for Pabs=150 kW and average line density $<n_e>=0.6\times10^{19}$ m^{-3}:

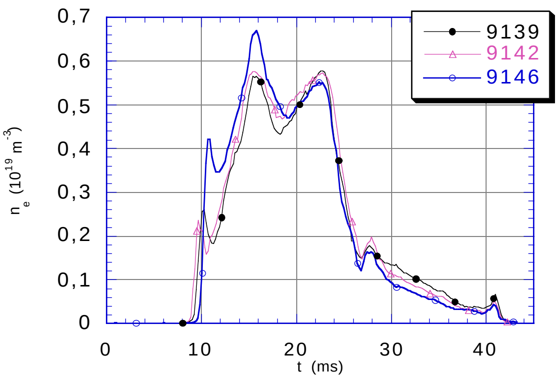

Figure 1: Line density of three typical TJ-IU discharges

LGS (ms)	=	0.5096	ms
W7AS (ms)	=	0.9177	ms
LHD (ms)	=	0.3571	ms
GRB (ms)	=	0.3571	ms
ISS (ms)	=	0.6864	ms
TORS (ms)	=	0.5022	ms

Therefore, it seems that TJ-IU scaling law corresponds to LHD or gyro radius-Bohm scaling. Both scaling laws give similar results for this low density and temperature regime. This is not surprising, since the magnetic configuration, of torsatron type, is similar to LHD one, and no

[1] E. Ascasíbar E. et al, Transactions of Fusion Technology **27** (1995) 198.
[2] F. L. Tabarés et al. Proc of 24th EPS conference. P2, p. 737. Berchtesgaden (Germany), 1997

losses optimisation was performed in the TJ-IU design. In figure 1 line density is shown for three typical discharges of TJ-IU. The discharge #9146 is chosen as a case example for transport analysis. The value of β for this discharge, given by magnetic diagnostics, is about 0.17 % in the steady state phase.

TRANSPORT ANALYSIS

Transport analysis is performed using the 1,5D predictive transport code Proctr[3] to estimate the main confinement characteristics of TJ-IU torsatron. The equation that governs the temperature evolution is given by the local power density balance[4]. In order to perform transport analysis, the terms in the equation have to be either measured or evaluated and then check that the simulation is compatible with the experimental results.

Ray tracing techniques show a poor single pass power absorption, so that a deposition profile for multi-reflection absorbed power is assumed. The values of radiated power and transport coefficients are deduced comparing the obtained confinement time using Proctr with LHD scaling law and fitting the experimental profiles of electron density and temperature.

RESULTS FOR STEADY STATE

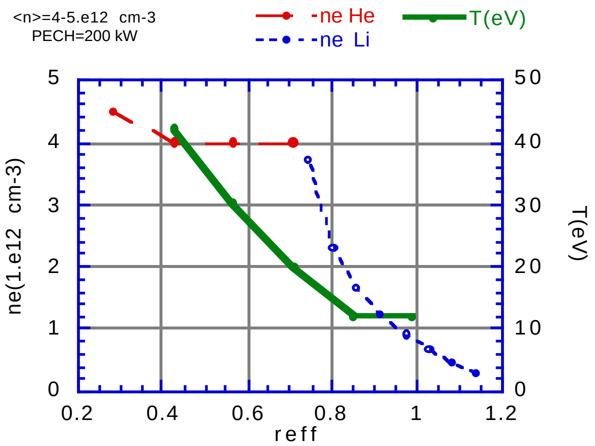

Figure 2. Experimental T_e and n_e profiles from atomic beams.

The experimental electron temperature and density profiles are shown in fig. 2 and are compatible with the ones obtained using Proctr. A comparison of temperature profiles is shown in fig. 3a. Power density balance equation terms and heat conductivity are shown in figs. 3b and 3c. It can be seen that the transport is strongly anomalous at the edge, where conductivity is two orders of magnitude over the neo-classical one. A comparison between the estimated neo-classical energy flux and the one deduced from the analysis shows that the latter is much higher than the neo-classical one. The power deposition profile is wide, as corresponds to this situation in which only about 20 % of the power is absorbed in a single pass. The ion energy confinement time is about ten times higher than the electron one, being the latter very similar to the global energy

[3] H. C. Howe. “Physics models in the toroidal transport code Proctr” Re. ORNL/TM-11521, Oak Ridge Nt. Lab., TN (1990)

[4] F. Castejón et al. Poster at this conference.

confinement time, which means that the main energy channel loss is the electron one. Neo-classical particle transport is compatible with the measured density profile.

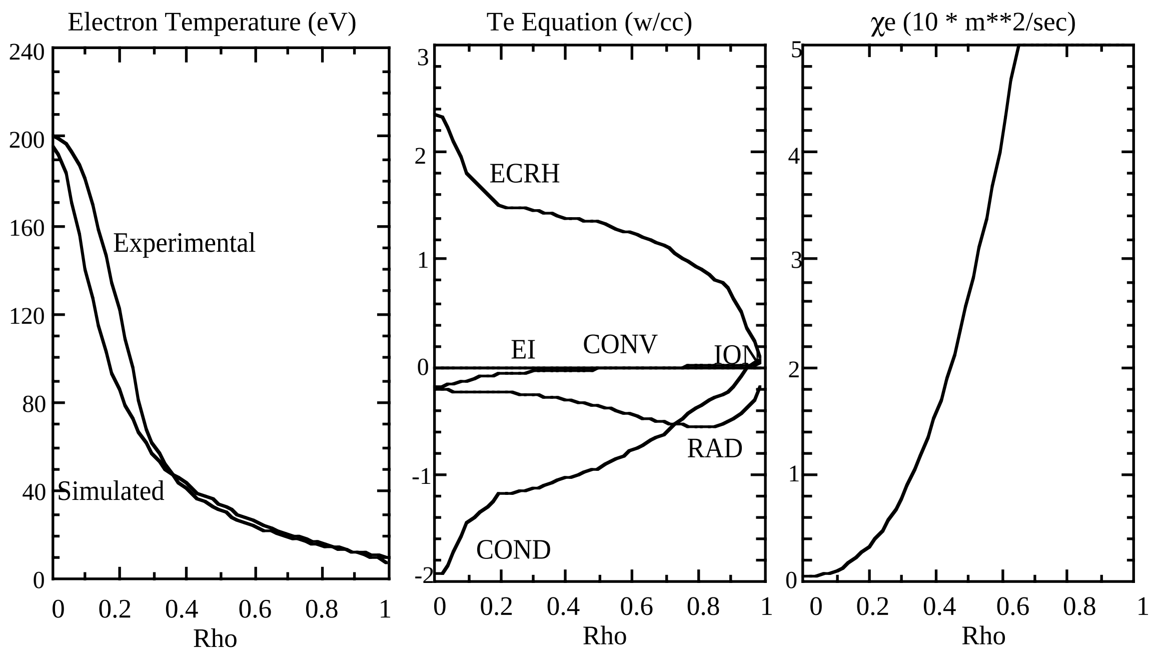

Figure 3: Experimental and simulated temperature profiles, local power density balance equation terms, and electron heat conductivity for discharge #9146.

PERTURBATIVE EXPERIMENTS

Perturbative experiments to analyse the dynamical transport properties have been carried out in TJ-IU. Time evolution of temperature and density in time intervals of some ms can be obtained and compared with Proctr simulations.

The evolution of the density profile after puffing turn-off has been used to obtain the particle diffusion coefficient. Experimental density evolution is plotted in fig. 4, where it can be observed that density profile starts suffering the effect of the end of the puffing at the plasma core. On the other hand Proctr has been used to simulate the density evolution of the discharge and the result is shown in fig. 5. A qualitative agreement is obtained in the general behaviour, but not in the profile response to puffing

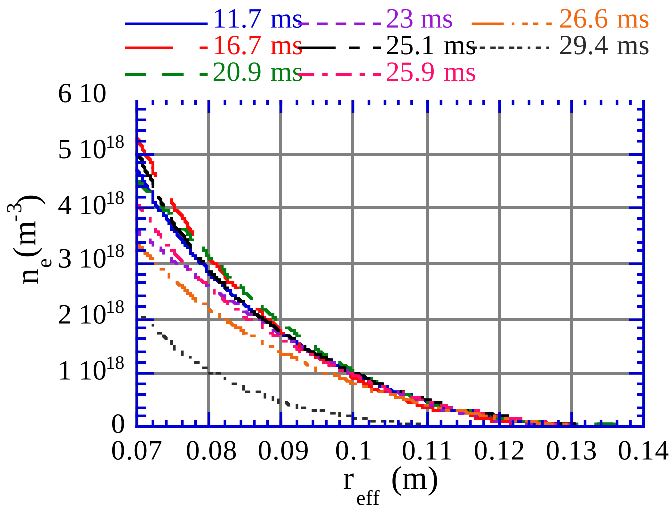

Figure 4. Evolution of experimental profile density.

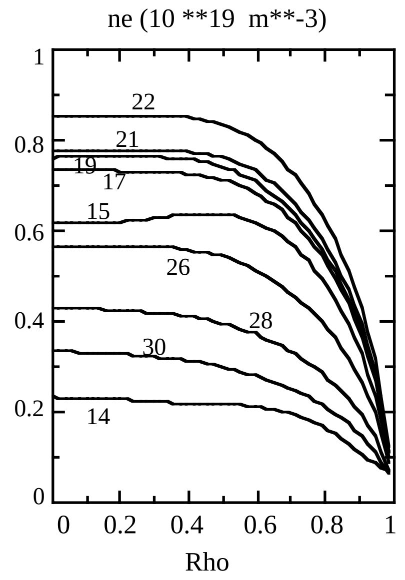

Figure 5: Simulated evolution of density profile.

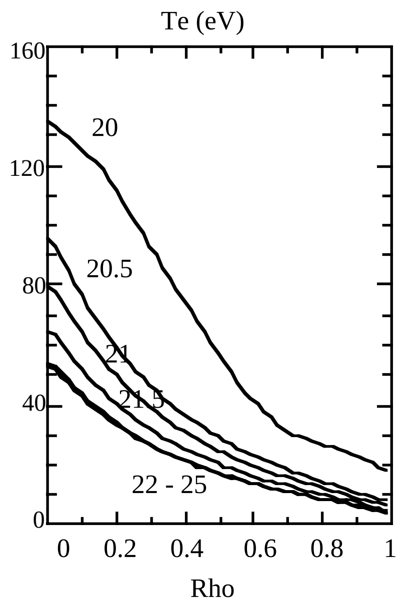

Figure 6: Simulated evolution of T_e profile after Ar puffing (t=20 ms).

turn-off, when simulated density profile falls at the same rate at the centre and at the edge. An "effective diffusion coefficient" is calculated assuming that the falling of density is only due to a diffusive process and has a Bohm like behaviour at the edge. This coefficient ranges approximately in the values 0.4 to 0.8 m^2/s, to be compared with the value of diffusivity at these radii given by Proctr, of about 2 m^2/s. The difference between both figures can be due to the fact that the evolution of density profile cannot be attributed only to particle transport, and there are other phenomena, like recombination and recycling, involved in the process.

In addition, the effect of fast injection of Ar on the edge profiles is studied. For that purpose, a fast (rise time<100 μs) piezo valve was used for a short (<0.3 ms) puffing of this species into the 20 ms plasma pulses. Electron temperatures evolution are determined by a pulse He beam (Δt=2 ms) synchronised to the Ar pulse[5]. The propagation of the temperature perturbation in the radial direction was,. therefore, followed in a shot to shot basis. It has been chosen the shot #8923, that shows a strong modification of temperatures at the edge, that fall about a factor 2 in 1 ms, and a strong increase of line density. The perturbation has also been simulated using Proctr, and a qualitative agreement is found between simulated temperature profile and the experimental one. Following the propagation of the cold pulse it is obtained a thermal conductivity that ranges between 10 and 40 m^2/s. This value is lower but similar to that used in Proctr to simulate the same phenomenon, of 100 m^2/s, considering experimental uncertainties.

CONCLUSIONS

Experimental electron temperature and density profiles have been obtained for TJ-IU torsatron, which allows to simulate plasma evolution in this device using the 1,5D transport predictive code Proctr. Transport analysis has been performed in both perturbative and steady state, and the results of the simulation are compared with experimental ones.

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[5]F.L. Tabarés et al. Journal of Nuclear Materials, **241-243** (1997) 1228