*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-5.083 (2006)*

Effects on impurity transport of the active control of the magnetic boundary in RFX-mod

L.Carraro, E.Gazza, R.Lorenzini , M.Mattioli , M.E.Puiatti, P.Scarin, M.Valisa , B.Zaniol

Consorzio RFX - Associazione Euratom-Enea sulla Fusione,Padova,Italy

Abstract

Previous analysis of impurity transport in the RFX device, where a thick passive conducting shell was used for the stabilisation of the MHD modes, had shown a highly anomalous diffusion coefficient of the order of 10-20m^2/s in the central plasma (r/a<0.8), decreasing to about 1-2 m^2/s at the edge, with a pinch velocity changing from outward to inward at r/a ~ 0.8[1]. This paper presents the carbon and oxygen transport investigations performed on the new version of the machine, RFX-mod, where a set of 4x48 saddle external coils allows a better control of the radial magnetic field at the edge resulting in a significant reduction of the amplitude of the MHD modes (about an order of magnitude) and of the heat transport. The impurity diffusion coefficient and the pinch velocity have been determined in such a way to best reproduce with a 1-dim Collisional-Radiative (CR) model all the available spectroscopic data.

The conclusion is that the same transport coefficients found for the old RFX allow the best experimental data simulation in spite of the lower magnetic fluctuation level.

The impurity transport coefficients determined in this way have also been compared with those calculated taking into account classical particle collisions and diffusion in a stochastic magnetic field in a large part of the plasma core region (up to r/a=0.9): though much lower in the core, the diffusion coefficient calculated according to the theory has a similar shape if compared with the empirical one. The simulation of spectroscopic data requires that the convective velocity changes direction more internally than predicted by the theory.

Results and discussion

To determine the impurity diffusion coefficients suitable to describe the RFX-mod experimental situation and to compare them with the old RFX ones, an analysis as complete as possible of all the experimentally available information relevant to the impurity behaviour has been performed and reproduced with a 1-dimensional CR impurity transport model [1] .

The radiation from Carbon and Oxygen, which are the main plasma impurities, has been simulated by means of a 1-dimensional Collisional-Radiative (CR) transport model with boundary conditions compatible with the measured influxes from the wall. The code has been used to reproduce line emissivities (CV,CVI,OVII lines), SXR (brightness time evolutions and profiles) and Z_{eff}. In Fig.1 the experimental electron temperature and density time evolutions and profiles are shown .

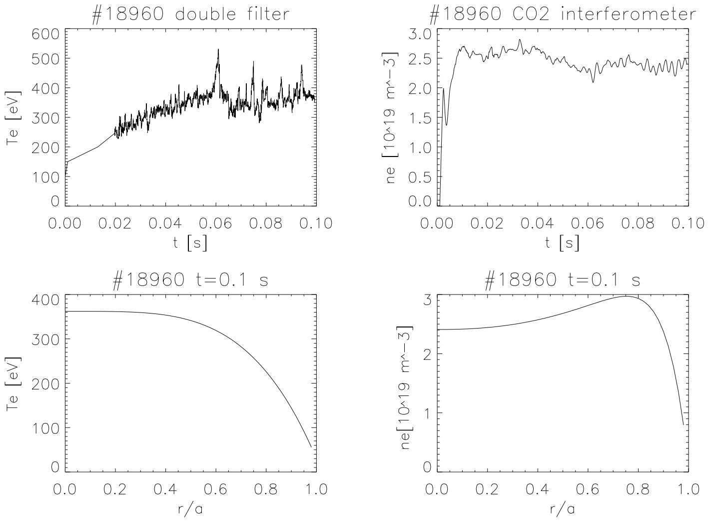

Fig.1 Time evolution of T_e and n_e as obtained with double filter and interferometer diagnostics respectively. The profiles (from Thomson Scattering and CO2 interferometer measurements) during the flat top phase are also drawn.

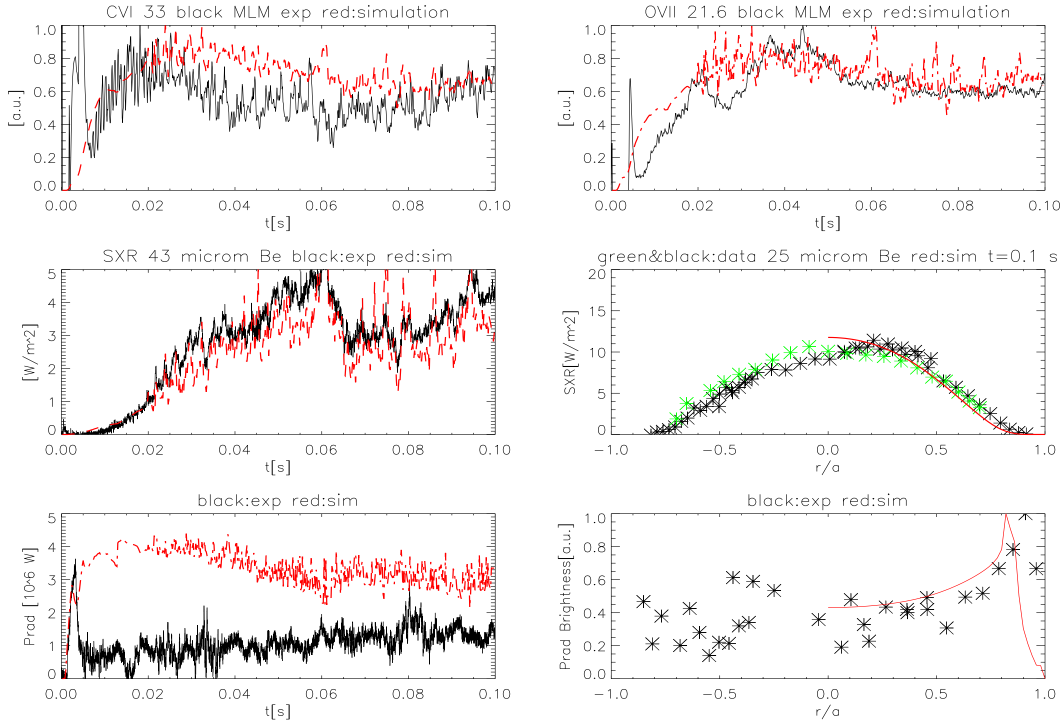

Fig.2 RFX-mod #18960 discharge, experimental and simulated signals (in red). From top to bottom: resonance lines of CVI and OVII time evolutions as measured by the multi-layer mirror monochromators, SXR time evolutions and radial profile during the flat top phase, total radiated power and normalized brightness profile. Carbon and oxygen concentrations obtained from the model are also compared with the measured emissivities of CV 2271A and OVII 1623A, obtained in RFX-mod with an absolutely calibrated spectrometer

In figure 2 experimental and simulated signals are compared. Agreement within +/- **20**% among the simulated and measured quantities is found, with a difference by a factor 2 between the simulated and measured radiated power: this larger discrepancy can be explained considering that the model is cylindrically symmetric, while toroidal and poloidal asymmetries are found in the plasma radiation pattern([2], see also the bottom-right subframe of fig.2). The satisfactory result of the comparison among simulation and experiments confirms the low contamination level already found in the RFX plasma and is obtained with the same impurity transport parameters found for the RFX plasma (see Fig.3). The result of the analysis is in fact that, accounted for the higher electron temperature reached in the new plasma scenario of RFX-mod, the diffusion coefficient and the pinch velocity suitable to reproduce the plasma emission scenario are not different from the old ones. The diffusion coefficient at the edge is lower than in the plasma core, the convective velocity is inward at the edge and outward in the plasma core. Analysing the density behaviour the same conclusion can be drawn: particles confinement seems to be not influenced by the heat transport reduction observed in RFX-mod with the active control of the magnetic boundary [3]. The diffusion coefficient found for the main gas and for the impurities are of the same order (a very weak dependence on the mass is therefore found), while the flat or hollow experimental electron density profiles imply an outward convective velocity throughout the plasma (anti-pinch term), without the inversion of direction found at the edge for the impurities.

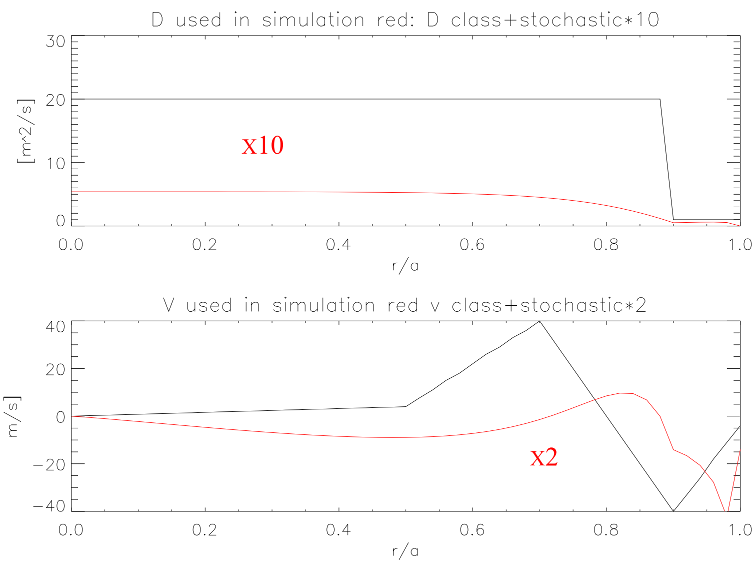

Fig.3 Diffusion coefficient and convective velocity used in the model to best reproduce RFX-mod plasma emission signals (black lines). The transport parameters as obtained considering particle collisions and diffusion through a stochastic field are also reported (red lines) .

The impurity transport parameters (D and V) obtained from the reconstruction of the spectroscopic data, can be compared with those predicted by a stochastic magnetic field diffusion model in the core and a classical collisional mechanism at the edge [4,5], the results are also drawn in Fig. 3.

A step-like $D_{stochastic}$ profile is assumed, flat in the core (where the magnetic fluctuations are likely to be uniform) and sharply going to zero at r/a ~0.9; following the measurements of field errors at the edge, with respect to the RFX scenario a reduced core magnetic fluctuation magnitude by a factor three has been assumed. The radial shapes of the predicted diffusion coefficient and velocity are similar to those of the empirically determined parameters, but they are much lower and the predicted velocity changes its direction more externally. Despite the reduction of the magnetic fluctuations by a factor 3 (corresponding to a field line diffusion coefficient reduction by a factor 5 if a power dependence $(dB/B)^{1.5}$, as is assumed in [6]), the same RFX transport parameters are found for the new machine RFX-mod. This means that the differences in magnitude between the 'experimental' transport parameters and those predicted considering a stochastic+classical impurity transport scenario results deeper than for the old RFX [3].

Conclusion

The state of the art of the impurity transport analysis in the RFX-mod reversed field pinch machine has been presented. The impurity diffusion parameter and particle velocity have been determined reconstructing all the available spectroscopic measurements with a 1-dimensional collisional radiative impurity transport code. The resulting transport parameters have been compared with those calculated considering the classical collisional particle diffusion and diffusion across a stochastic field in the plasma core. The shapes of the empirical and of the theoretical parameters are similar but the 'stochastic+classical' magnitudes are much lower. As for the main gas, the same impurity diffusion parameters of the old RFX have been found, despite the reduced error field. The anomaly in the impurity transport parameters has not been explained and more efforts are needed to find a theoretical scenario allowing a proper description of the particle behaviour in RFX-mod.

Acknowledgement *This work was supported by the European Communities under the contract of Association between EURATOM/ENEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission*

[1] L.Carraro et al. Plasma Physics and Controlled Fusion 42, (2000), 731
[2] L.Carraro et al XXXII EPS Conference Terragona 27 June-1 July 2005 P2.03
[3] R.Lorenzini et al. this Conference P5. 082
[4] L.Carraro et al XXX EPS Conference S.Petersburg July 7-11 2003 P3.22
[5] J.Y.Hsu,R.W. Harvey, S.K.Wong, Physics of Fluids 24(12) (1982) p.2216.
[6] F.D'Angelo, R. Paccagnella, Plasma Phys. and Controll. Fusion 41(1999) 941