Evidence of transport barrier in TCABR tokamak with high MHD activity

2011 J. Phys.: Conf. Ser. 285 012010

(http://iopscience.iop.org/1742-6596/285/1/012010)

Evidence of transport barrier in TCABR tokamak with high MHD activity

G. Z. dos Santos Lima[1], F. A. Marcus[2], I. L. Caldas[3], Yu. K. Kuznetsov[3], I. C.Nascimento[3]

[1]Department of Science and Technology: Federal University of Rio Grande do Norte, 59014-615, Natal, RN, Brazil
[2] Department of Naval Architecture and Ocean Engineering, University of São Paulo, 05508-970 - São Paulo, SP, Brazil
[3]Institute of Physics, University of São Paulo C.P. 66318, 05315-970 São Paulo, S.P., Brazil

E-mail: gzampier@ect.ufrn.br; ibere@usp.br

Abstract.
In this work we analyze the particle transport at the plasma edge during TCABR tokamak discharges with high MHD activity. The interpretation of this transport as chaotic, in a quasi integrable Hamiltonian system formed by the plasma flow and the drift waves, predicts its dependence on a confinement parameter, proportional to the difference between the plasma flow and the drift wave phase velocities. For the analyzed discharges, we observe a particle transport decrease where the confinement parameter has a maximum. In the considered quasi integrable description, this can be interpreted as an evidence of a localized transport barrier.

1. Introduction

Plasmas have been magnetically confined in tokamaks to investigate the possibility of generating energy from controlled thermonuclear fusion [1, 2]. One of the main problems to confine plasma in tokamaks is the anomalous loss of particles at the plasma edge [3]. It is believed that this transport of particles is related to the plasma turbulence due to drift waves [4, 5, 6].

Understanding the transport of particles in the tokamaks has a fundamental importance to improve plasma confinement [7, 8]. Recent theoretical studies [9] and experimental results in tokamaks [10] showed that transport barriers may arise at plasma edge, under some condiction, increasing the plasma confinement [6].

Unlike most tokamaks, in TCABR the frequency spectra of electrical and magnetic fluctuations have a peculiar partial superposition [11, 12]. Moreover, in some electrical discharges the MHD activity can enhance and modulate the electrostatic turbulence at the plasma edge [7, 8], coupling and synchronizing with the electrostatics fluctuations [12]. Furthermore, for plasma discharges with high MHD activity, the transport is high where a resonance condition is satisfied [7, 8], i.e, where the drift velocity associated to the radial electric field and toroidal magnetic field components is equal to the drift wave phase velocity.

Some transport properties in TCABR tokamak discharges, with high MHD activity, have been interpreted as a consequence of the chaotic particle motion due to drift waves propagating in the plasma edge with $\vec{E} \times \vec{B}$ poloidal flow. This chaotic motion has been described by a two wave quasi integral Hamiltonian model, which predicts a transport dependence on a confinement parameter, proportional to the difference between the plasma flow and the drift wave phase velocities [9, 13]. In this work, for the analyzed discharges, we present an evidence of a particle transport decrease where the confinement parameter has a maximum. In the considered quasi integrable description, this can be interpreted as an indication of a transport barrier at the plasma edge.

The remainder of the paper is organized as follows: Section 2 is a brief description of the TCABR experimental setup. Section 3 contains the experimental results about the relation between the drift and wave phase velocity difference and the barrier transport. This is followed by Section 4, consisting of our analysis conclusion.

2. Experimental setup

The experiments analyzed were performed in a hydrogen circular plasma in the TCABR tokamak [13], which has the major radius equal to $R = 61$ cm and minor radius equal to $a = 18$ cm (shown in Fig.1). The maximum value of the plasma current is around 110 kA, with duration 100 ms, as well as the hydrogen filling pressure presents 3×10^{-4} Pa, and toroidal magnetic field is $B_T = 1.1$ T. The fluctuations was measured by two Langmuir probes [Fig.1], poloidally separated by 0.4 cm. The probes are mounted on a movable shaft that can be displaced radially from $r = 15.0$ to 22.0 cm, with respect to the center of the plasma column. We take the range from 16.5 to 21.0 cm in order to cover the entire region of the plasma edge. The probe displacement occurs only for separate discharges in order to not disturb the plasma confinement and stability. The measurements were performed at a sampling frequency of 1 MHz.

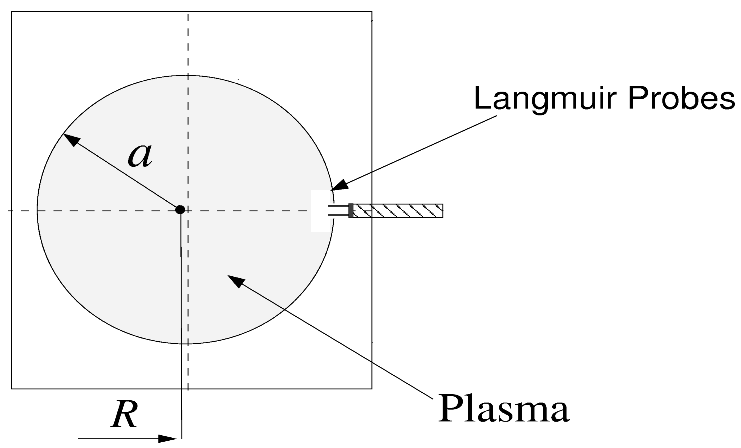

Figure 1. Cross section of the TCABR tokamak showing the Langmuir probes and plasma column.

During TCABR tokamak discharges with high MHD activity, the electrostatic plasma edge turbulence and particle transport are strongly influenced by the MHD activity. This high MHD activity can be obtained in two different regimes of TCABR discharges. In one regime, the enhancement of MHD activity was observed only after the activation of a biasing electrode while, in the other regime, this enhancement occurs spontaneously without activation of the electrode. In this article, we considered the second TCABR regime.

The evolution of a plasma discharge (number 18352) in TCABR is depicted in the Fig.2. The plasma current [Fig.2(a)] grows slowly for the first 85 ms, decaying slowly after that. The electron density evolution, indicated in the Fig.2(b), exhibits an evolution with a plateau level reach around $n_e = 1.2 \times 10^{19}$ m^{-3} in the region analyzed between vertical lines. The amplitude of the magnetic oscillations, shown in Fig.2(c), starts increasing at $t = 78$ ms and stays high until $t = 100$ ms. The time evolution of the ion saturate current is shown in Fig.2(d). The vertical black lines indicate the time interval with high MHD activity.

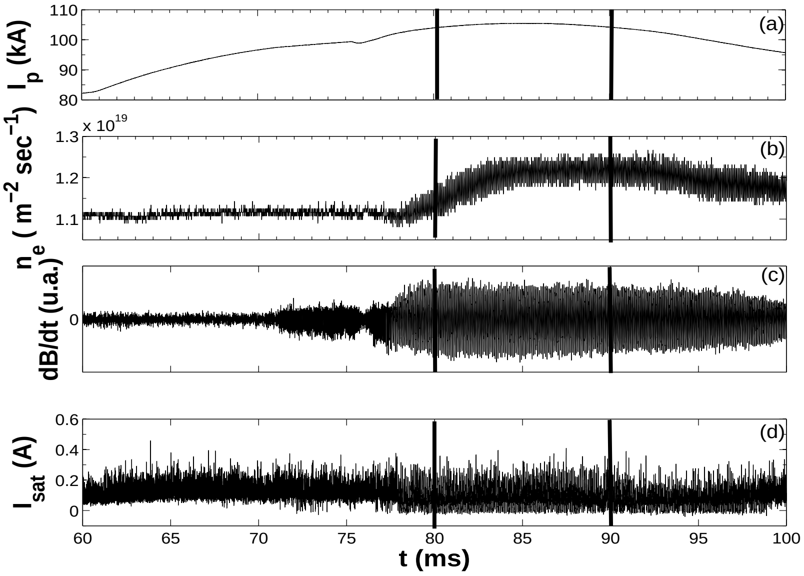

Figure 2. Time evolution of plasma discharge in TCABR tokamak. (a) Plasma current, (b) central chord plasma mean density, (c) magnetic oscilation, (d) ion current saturation. The vertical black lines indicate the analyzed time interval with high MHD activity.

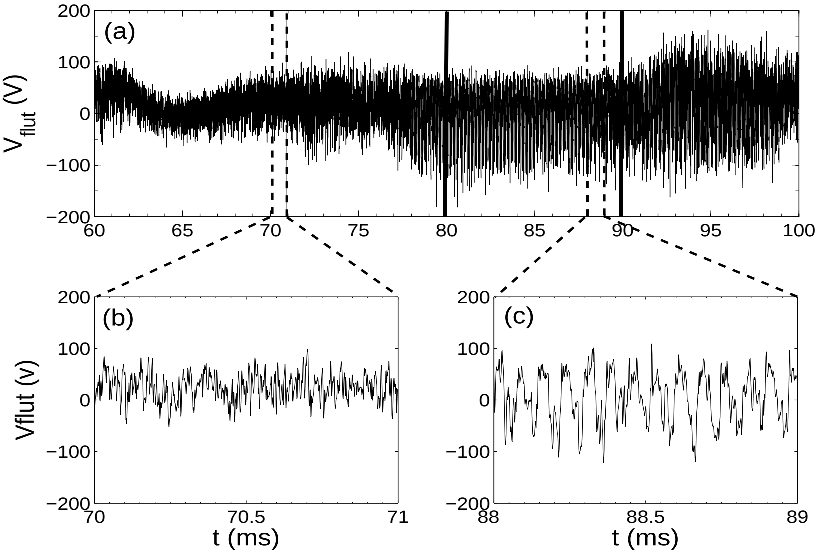

Figure 3. Time evolution of floating electrostatic potential fluctuation (a). Amplified time intervals with low MHD activity (b) and with high MHD activity (c) (dashed vertical lines). The vertical black lines indicate the analyzed time interval with high MHD activity.

The fluctuation we particularly studied was the floating electrostatic potential and a representative example is depicted in the Fig.3(a). The MHD activity change significantly the floating electrostatic potential as we present in the Figures 3(b) and 3(c); two diferent time intervals with low and high MHD activity respectively. All analyzed data were chosen during time intervals represented by the window indicated by full vertical lines (see Fig.3). We choose this time interval window before MHD activity starts to increase and changing the plasma turbulence [7, 10, 12].

3. Evidence of transport barrier in TCABR tokamak: Results and Discussion

Experimental results presented in this paper, on the drift and phase velocities difference and transport barrier at TCABR plasma edge and scrape-off layer [10], give us important evidence for the Hamiltonian model presented in Ref.[6, 9]. In this model there is a function, the trapping profile (U), proportional to the difference between the dominant wave phase velocity and the drift flow velocity, that determines the chaotic particle transport in the radial direction [14]. Thus, where the trapping profile ($U(x)$) is zero a resonance condition exists and a high radial particle transport is predictable. In contrast, where $dU/dr = 0$ the particle flux should be low.

To search for these theoretical predictions, we analyze data from several discharges (18346 t0 18379) and drew in the Fig.4 the radial profile of the averages phase velocity (v_{ph}), the drift velocity ($v_{\vec{E}\times\vec{B}}$) and the difference between these velocities, proportional to the experimental trapping profile, i.e, $U(r) \propto \frac{1}{B_\phi}\frac{dV_{flut}}{dr} - v_{ph}$.

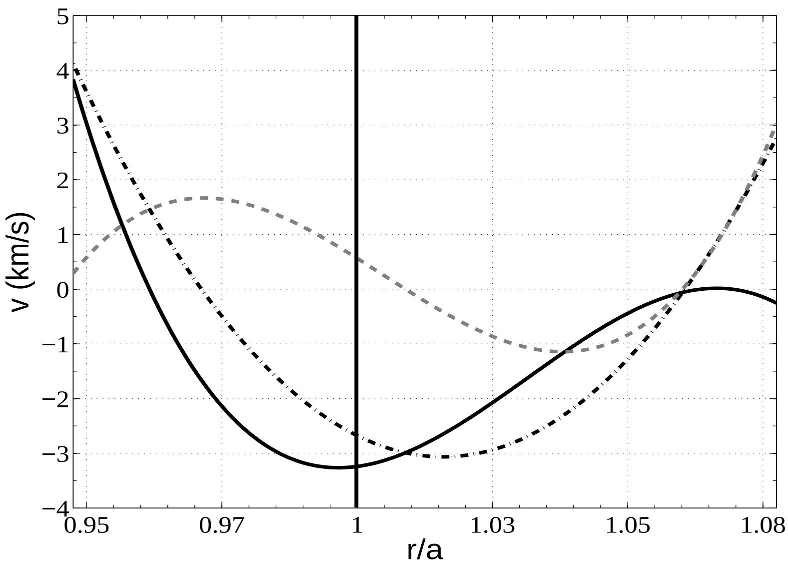

Figure 4. Radial profile of the averages phase (black line) and drift (dot-dashed line) velocities, and the difference between these velocities (dashed line)

Figure 5 shows the radial profiles of the experimental particle transport (triangle up) and the difference between phase and drift flow velocities $U(r)$ (dashed line). We observe a particle transport decay in the region where the difference between velocities has a local maximum ($dU(r)/dr = 0$) at ($r/a = 0.97$), corresponding to a shearless point. This decay indicates a possible transport barrier at this position, as predicted in [6, 9] and observed in [10]. Thus, the localized transport decay may be an indication of a transport barrier localized on the shearless region (indicated by a vertical arrow in Fig.5).

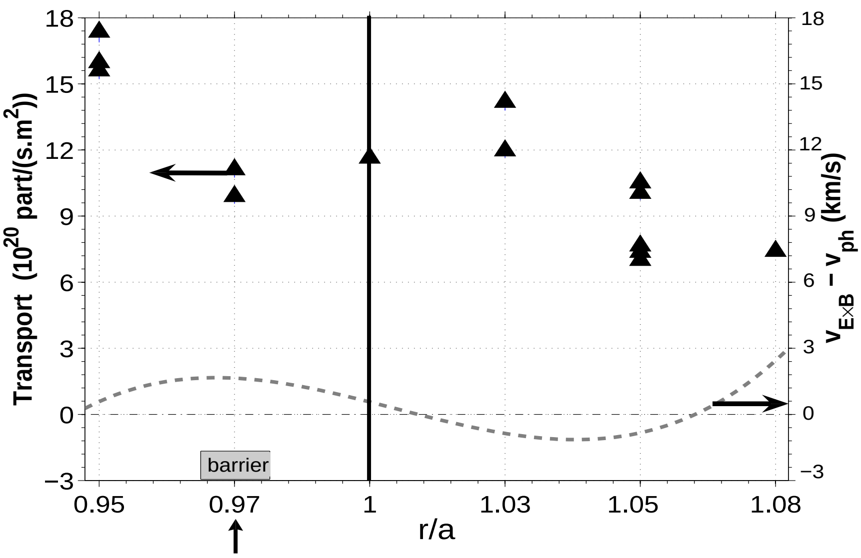

Figure 5. Radial profile of particle transport and the difference between the phase and flow velocities. Transport barrier localized on the shearless region on r/a =0.97(indicated by the vertical arrow).

Our transport barrier prediction is based on radial profiles obtained by analyzing probe data from different radial positions in a sequence of similar discharges. This prediction should be further confirmed in new experiments with simultaneous probe measurements in different radial positions. Moreover, the uncertainty in Figs. 4 and 5 profiles justify new measurements to better precise the barrier localization.

4. Conclusion

Analysing the radial profile of turbulence and transport of particles of the TCABR plasma discharges with high MHD activity, we found evidence that the particle transport decreased where the difference between phase and drift velocities had a local maximum. Although the experiment was not performed to verify any theoretical model, we used a chaotic two wave Hamiltonian model to interpret this result as an indication of the existence of a transport barrier created in the radial position where the drift flow shear vanishes.

Acknowledgments

This work was made possible with the help of FAPESP, CNPq, CAPES and UFRN.

References

[1] Jeffrey F 1990 *Plasmas Physics and Fusion Energy* (Cambridge)
[2] Gross R A 1984 *Fusion Energy* (John Wiley and Sons)
[3] Hazeltine R D and Prager S C 2002 *Physics Today* **55** 30
[4] Wesson J 2004 *Tokamaks* (Oxford University Press, 3rd Edition)
[5] Hidalgo C 2004 *Astrophysics and Space Science* **292** 681
[6] Horton W 1999 *Review of Morden Physics* **71** 735
[7] dos Santos Lima G Z and et al 2009 *Physics of Plasmas* **16** 042508
[8] Guimaraes-Filho Z O and et al 2010 *J. Phys.: Conf. Series* **246** 012014
[9] Marcus F A and et al 2008 *Physics of Plasmas* **15** 112304

[10] dos Santos Lima G Z 2009 *Análise da Turbulência do Plasma no Tokamak TCABR* (Ph.D. thesis, Intitute of Physics, University of São Paulo)
[11] Heller M V A P and et al 2007 *Journal of Plasma Physics* **73** 295
[12] Guimaraes-Filho Z O and et al 2008 *Physics of Plasmas* **15** 062501
[13] Nascimento I C and et al 2005 *Nuclear Fusion* **45** 796
[14] Horton W 1985 *Plasma Physics and Controlled Fusion* **27** 937