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Dependence of electron density profile on m=0 modes in the RFX experiment

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1. Introduction

In RFP machines the stochasticization of magnetic field produced by the magnetic fluctuations is responsible for the transport in the region of plasma internal to the reversal radius. The main role in generating transport is attributed to the magnetic perturbations that are resonant in the internal region of the plasma (m=1 modes) and in the region of the reversal (m=0 modes).
In this paper we present an analysis carried out on a set of plasma pulses of the RFX machine, aimed at determining the influence of radial field perturbations $\hat{b}^r_{m,n}$ (with the usual notation: m poloidal wave number, n toroidal wave number) on the electron density profile.
In order to get this goal we compare the electron density profile of shots characterized by different values of mode amplitude, for m=0 and m=1 modes. The shape of the density profile results to be sensitive to the mode amplitude, becoming more hollow when the amplitude increases. Even though it is difficult to separate the effect of m=0 from that of m=1 modes, the leading parameter of this trend seems to be the m=0 amplitude, because the trend with the m=1 modes was less evident.
The modification has been related, by means of the theory of transport in a stochastic magnetic field [1], to an increase of the particle diffusion coefficient D in the region of the plasma next to resonance radius of m=0 modes.

2. Data selection and behaviour of density profile

The shape of density profile is known to depend on the plasma parameter I/N [2]. The profile is flat or slightly peaked when I/N is higher than 3.10^{-14} Am, while it is hollow when the value of I/N is lower.
Furthermore the shape is dependent also on the average density $< n >$ because the steepness of gradient at the edge increases with $< n >$. For these reasons we selected a set of shots having homogeneous values of the I/N parameter and average density, and with m=0 and m=1 amplitude in the whole range of RFX. The set should also represent the typical operation condition of RFX and have a sufficient number of accurate measurements of density. In RFX the electron density is measured by a 12-chords IR interferometer [2]. The normalized impact parameter p/a of chords ranges from 0.11 to 0.93. As indicator of the shape of the density profile we used the peaking factor $P_F = n_c/n_e$, where n_c is the central density and n_e is the density at the edge. n_c is estimated from the measures of two central chords 4A and 5A (p/a = 0.11), while n_e is estimated by means of the measures of the edge chord 8A (p/a = 0.665) which is available in the most of RFX pulses.
This choice allows us to select a group of about 80 shots where the I/N value is maintained between 1.7 and 2.3x10^{-14} Am. This interval corresponds to a variation of the plasma current I_p between 600 kA and 700 kA and to a variation of the central

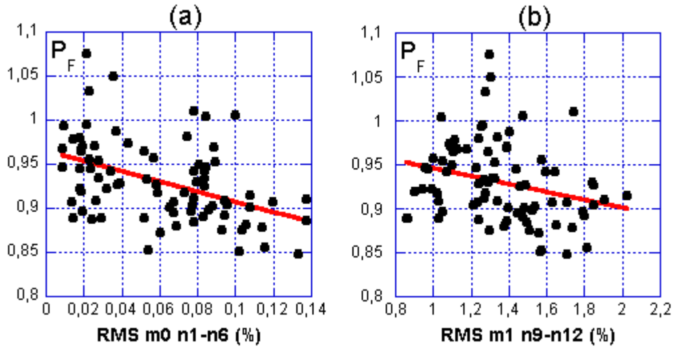

Figure 1: *Scaling of P_F with the RMS of m=0 modes (a) and of m=1 modes (b)*

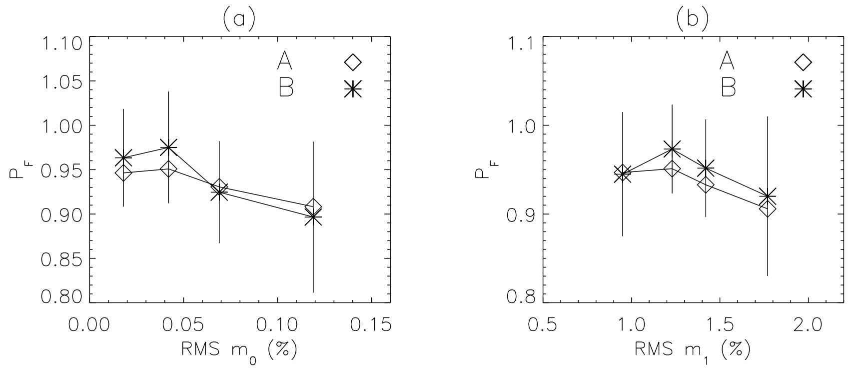

Figure 2: *Scaling of P_F with the RMS of m=0 (a) and the RMS of m=1 modes (b). P_F is calculated using the chord 8A (diamonds) or the chords 6B and 2B (stars). The points are representative of shots with similar mode amplitudes.*

density n_e between 3.5x$10^{19}m^{-3}$ and 4.5x$10^{19}m^{-3}$. The density measurements, as well as the other plasma parameters, are averaged on 10 ms during the stationary phase of the density evolution. The radial magnetic eigenfunctions are recostructed with a model [4] for low β plasma in toroidal geometry which takes into account the toroidal coupling between modes with the same toroidal number and different poloidal numbers. The eigenfunction amplitude $\hat{b}^r_{m,n}$ at the resonance radius, normalized at the poloidal field at the edge $B_\theta(a)$, is taken as indicator of the effect of m,n perturbation on particle transport. The effect of m=1 modes and of m=0 modes on transport is estimated taking the RMS respectively of $\hat{b}^r_{1,n}$ and of $\hat{b}^r_{0,n}$. In order to keep separated the effect on the density of m=0 and m=1 modes only the m=0 n=$1-6$ modes are considered, because the spectrum of m=0 with n$\geq$ 7 receives a significant contribution from the toroidal coupling of m=1 modes. Furthermore, to look at the magnetic chaos generated by m=1, we excluded from the RMS the modes with n=7,8, that usually dominate the m=1 spectrum.

This choice allows us to include in the analysis also the QSH shots, that, despite the high amplitude of the dominant mode, are less chaotic than standard shots because the amplitude of secondary modes is very low.

Figure 1 shows the scaling of the P_F with the RMS of m=0 and of m=1 modes. The shape of density profile changes from flat ($P_F \simeq 0.96$) to hollow ($P_F \simeq 0.89$) when the RMS of m=0 modes increases, and it shows a similar behaviour when the

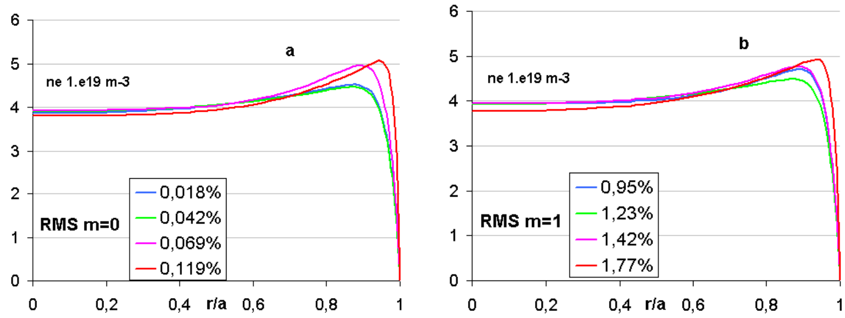

Figure 3: *Representative density profiles for the classes of m=0 modes (a) and for the classes of m=1 modes (b)*

amplitude of m=1 modes increases. Despite the decoupling of perturbations spectra a correlation between the RMS of m=0 modes and RMS of m=1 modes is present and makes it difficult to understand if the scaling of P_F is due to m=0 or to m=1 modes. In order to understand which is the leading parameter of this trend we grouped the shots with similar m=1 amplitude in four classes and we looked at the trend of P_F with the m=0 amplitude inside each class. In an analogous way we grouped shots with similar m=0 amplitude in four classes to look at the trend of the peaking factor with the m=1 amplitude inside each class. A decrease of P_F with the m=0 amplitude in the m=1 classes is clearly present, while P_F decreases when the m=1 amplitude increases in two classes, and increases in the other two.

In order to use the chords more external than the 8A we have to use a larger data set where n_e varies between 3x10$^{19}m^{-3}$ and 5x10$^{19}m^{-3}$ and I_p varies between 500 and 700 kA. For this larger set, which contains about 150 shots, is possible to investigate the scaling of P_F also using the measurements of chords 6B and 2B ($p/a = 0.753$) to calculate n_e. Figure 2 compares the scaling of P_F calculated with the 8A chord and 2B-6B chords, with the RMS of m=1 and m=0 modes. The points are averages on four classes of shots having similar mode amplitudes and are plotted versus the average mode amplitude of the classes. The B chords confirm the trend of P_F with the m=0 mode amplitude which is also evident in the measures of A chords. The scaling with the m=1 modes is less evident, because the shape of density profile changes only when the mode amplitude is particularly high. Using the information of all the interferometer chords allows us to reconstruct the density profile in detail. The density measures of each class of mode amplitude have been averaged in order to obtain four sample shots. By means of the inversion code we calculated, for each sample pulse, the corresponding density profile. Figure 3 shows the representative density profiles for the classes of m=0 and m=1 modes. The results confirm that the density profiles become increasingly hollow when the mode amplitude increases. This trend seems to be clearer when the dependence on m=0 modes is analysed. The profile of the third class is hollower than the first two profiles, and the hollowest profile corresponds to the class with the highest mode amplitude.

3. Particle transport analysis

A particle transport analysis has been performed in order to study the behaviour of the particle diffusion coefficient D. The particle transport code TED [3] has been used, assuming a model based on the theory of transport in a stochastic magnetic field.

The simulations have been performed on the sample shots representative of the lowest and highest m=0 mode amplitude, that are also representative of the shots with low and high m=1 amplitude. The figure 4 shows the radial profile of the particle transport coefficient D that allow to reproduce the density measures of these two shots. The dashed lines represent the error bars. The different shape of the density profiles is related to different plasma transport properties in the external region ($r/a \sim 0.85$), next to reversal radius. The two D profiles do not show any difference in the central region, where the m=1 modes are resonant, while in reversal region, where m=0 modes are resonant, clearly differ.

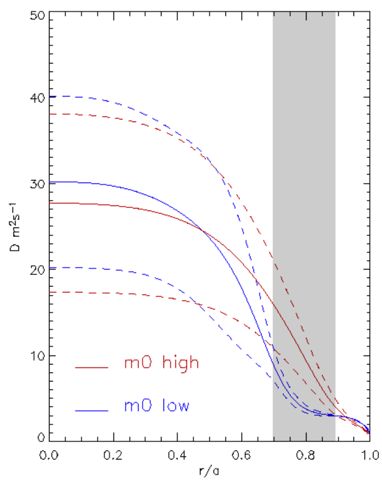

Figure 4: *Profile of D for the two sample pulses with the lowest and the highest m=0 value. Error bars are in dashed line. The shaded area shows where the two profiles differ.*

4. Conclusions

The analysis presented in this paper shows that the shape of density profile depends on the magnetic mode amplitude. The density profile becomes increasingly hollow when the mode amplitude increases. Due to the correlation between the m=0 and m=1 mode amplitude is difficult to separate the effects of these types of modes. However the effect on the density is more evident when the dependence on m=0 modes is analysed. Furthermore particle transport analyses show that the modification of D profile which accounts for the different shape of density profile is located in the external region of the plasma where the m=0 modes resonate. All these results allows us to conclude that a leading role is played by m=0 modes in influencing the particle transport.

5. Acknowledgement

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