Here, $r_p = |d \ln p/dr|^{-1}$ is the pressure scale length and $s = (r/q)\, \partial q / \partial r$ is the dimensionless shear.

For the Ohmic case, a factor close to $(\beta_e q^2)^{-\frac{1}{2}}$ was deduced from a model based on drift-tearing instabilities and magnetic reconnection /10/. These modes are driven by the current density gradient. It is likely that the α increase with heating power and beta in the intermediate region reflects the growing contribution of pressure-driven modes, e.g. resistive ballooning modes, to magnetic turbulence induced transport.

It is concluded that the empirical χ_e scalings in the OH, L and H regimes are incompatible with purely electrostatic drift wave turbulence. Inclusion of electromagnetic effects yields the β_e^{-1} scaling but fails to explain the factor $(\beta_e q^2)^{\alpha}$ which is indicative of resistive ballooning or interchange instabilities. The different scalings in the OH and L, H regimes result from changes in this finite pressure contribution and thus in magnetic turbulence induced transport.

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CHANGES IN THE DENSITY PROFILE DUE TO THE m=2 TEARING MODE IN ASDEX

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1 - Introduction

Resistive MHD tearing modes can develop magnetic islands near the rational magnetic surfaces, where q=m/n. In some situations, depending on the shape of the current profile and on the radial position of the q=2 surface, the (m=2,n=1) rotating structure of growing islands can come to rest ("mode locking"); in ASDEX, the so-called locked modes can be found for several plasma scenarios, and generally they are precursor to disruptions /1/.The magnetic structure of rotating tearing modes in a tokamak plasma is quite well known from the measurements of the modulations of the poloidal magnetic field. We have studied the effects on plasma density of large amplitude m=2, n=1 modes in ASDEX, using broadband microwave reflectometry.

2 - Density profile deformations

Reflectometric measurements were performed with the ASDEX O-mode reflectometric system, described in an acompanying paper /2/. Signals were obtained with two reflectometers (covering respectively the ranges 18-26.5 and 26.5-40 GHz), during Lower Hybrid Current Drive (LHCD) discharges. Results are shown concerning the shot 29285 where a locked mode occured between 1577 and 1585 ms, refering to: (a) magnetic island rotation at t=1565 ms, (sweep time t=2 ms), and (b) mode locking at t=1580 ms.

Before locking, the signals show both amplitude and phase modulations /2/ with the periodicity T of the tearing mode measured with the Mirnov coils, $T^{-1} = f_{rot} \simeq 1.4$ KHz. The spectrum exhibits several high amplitude peaks, related to the observed modulations (Fig.1a), showing the strong effect of the magnetic islands on the plasma profile. The phase shift, $\Delta\Phi/\Delta F$, of the plasma reflected microwaves (18-40 GHz) is presented in Fig.2a. It exhibits two disturbed regions: the beat frequency f ($f \propto \Delta\Phi/\Delta F$) decreases followed by an increase, corresponding respectively to outward and inward movements of the plasma layers, occuring during the 2ms (0.5 KHz) measuring time. The corresponding deformations can be seen on the evaluated profile (Fig.3a).

During mode locking, the signal at 26.5-40 GHz presents an abrupt increase in the beat frequency for microwaves with F>F'~31.2 GHz. The spectra exhibit two single peaks respectively at $f_1 \sim 22$ KHz and $f_2 \sim 40$ KHz (Fig.1b); the peak at f_2 can clearly be seen by performing a partial spectral analysis from F' to 40 GHz. The non existence of secondary peaks, (as observed in the frequency spectra before the locking), confirms that these are due to density perturbations induced by the rotating magnetic island m=2. The phase shift $\Delta\Phi/\Delta F$ (18-40 GHz) presents two abrupt jumps, (see Fig. 2b), revealing the displacement inwards of the reflecting layers with those densities. The density profile (Fig. 3b), presents two density plateaus, (corresponding to the phase shift jumps) respectively for: (1) r = 29-32.5 cm, and (2) r=39-40.5 cm.

The density outside (inside) the plateaus increases (decreases) and the density gradient decreases (increase) as compared to the profile measured before the magnetic islands develop. So it seems that the profile undergo a periodic deformation (T^{-1}) that is not limited to the regions where the plateaus occur.
The reflectometric antennae are located in the mid-plane, such that for the magnetic island with m=2 the toroidal angular distance to "O" point is ~ 150°, so the first measured plateau should roughly correspond to only 30% of the island width; this yields an island width of about 10 cm, centered at r ~ 30-31 cm, which is in agreement with the results derived from the magnetic data for the m=2 mode. The second plateau must likely be located near another rational surface and it will be the subject of further investigation.

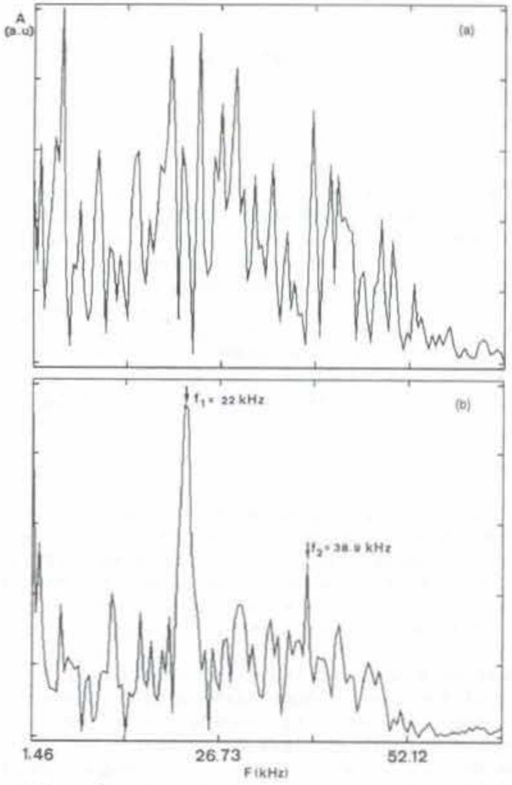

Fig. 1

3 - Numerical modelling

In order to have some insight about the characteristics of the perturbation originating the deformations of the profile during the island rotation a numerical study was performed, by considering a profile of parabolic shape with $neo=2.5*10^{13}$ cm^{-3}. The density effects due to the tearing mode with m=2 (n=1) were simulated by assuming a density plateau in

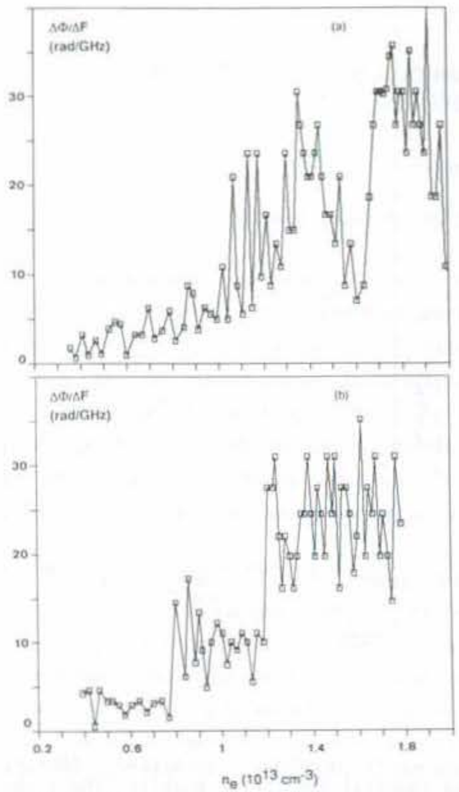

Fig. 2

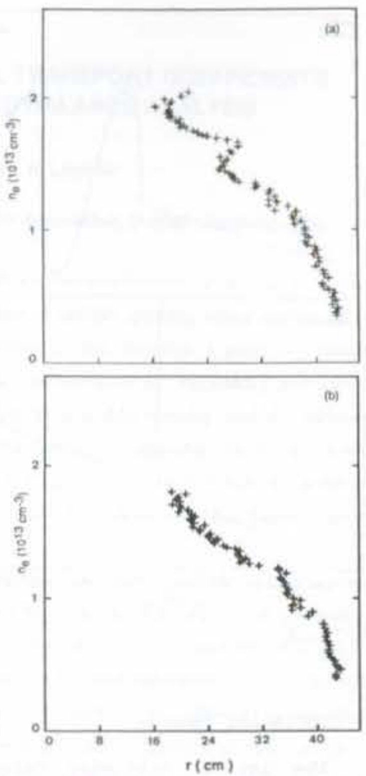

Fig. 3

the profile (q=2, near r ~ 30 cm) whose width can vary as the width of a rotating magnetic island observed in a fixed position (θ=0, in the mid-plane), i.e. $w*((1 + \cos(m\theta + \omega_{rot}t + \phi))/2)$. When the mode is locked, f_{rot} =0, ϕ =150°, and w(1580ms)=10 cm as concluded before; for frot=1.4 kHz, we consider w(1565ms)=8 cm, that takes into account the growing of the island before locking as evaluated from magnetic measurements. Fig.4 shows the numerically estimated microwave shifts for: (a) f_{rot} =1.4 KHz, (b) f_{rot} =0 KHz, and the corresponding profiles, Fig.5 (a) and (b), evaluated using the simulated phase shifts. Good agreement with the reflectometric measurements is obtained, namely in the observed perturbation when the island is rotating. From the observed deformation of the profile at t=1565 ms, it can therefore be concluded that a density plateau within the island structure (observed after mode locking, at 1580 ms) should already exist before mode locking occurs, rotating with the magnetic perturbation.

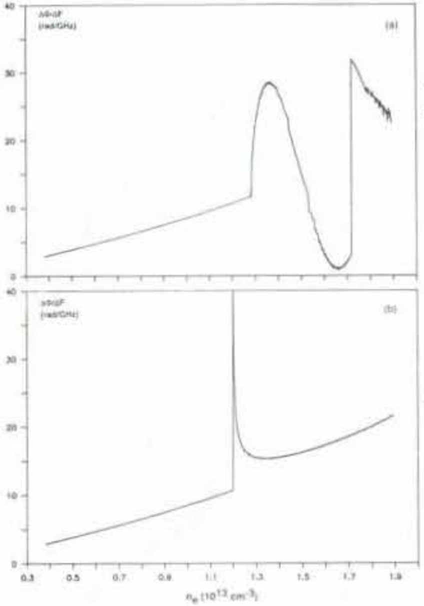

Fig. 4

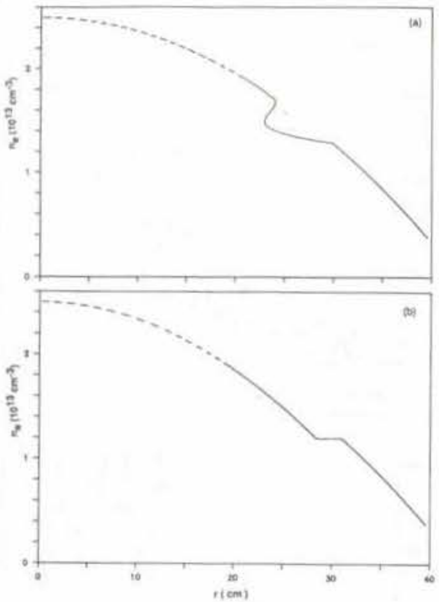

Fig.5

4 - Concluding remarks

The use of microwave reflectometry provided localized density measurements with good spatial and temporal resolution enabling the study of density perturbations due to m=2 tearing mode; the experimental results also indicates the existence of other density perturbations. Further work will aim at the study of the effect on density of the islands developed in other magnetic surfaces (namely q=3/2, q=5/2 and q=3), in order to have insight about the modifications caused by LHCD on the q-profile as compared with the ohmic regime. Experiments that will enable the obtention of a sequence of profiles during mode locking are foreseen; the study of the profile evolution might provide a tool to estimate the (nonlinear) growth of the magnetic islands, and therefore contribute to have insight about the behaviour of the plasma before disruption.

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DETERMINATION OF OFF-DIAGONAL TRANSPORT COEFFICIENTS FROM PARTICLE AND POWER BALANCE ANALYSIS

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1. Introduction

In ASDEX pellet injection and IOC discharges give rise to density peaking which cannot be explained by changes in the charged particle deposition profile. Besides a particular plasma boundary behaviour distinct changes in the bulk particle transport are necessary and can be described by an increase of $-v_p/D$ (the ratio of the inward drift velocity and the diffusion coefficient used to describe formally the particle transport) /1/. Common to all cases with peaked density profiles - having $\eta = (\nabla T/T)/(\nabla n/n) = L_n/L_T < 1$ - is that they show an improvement in energy and impurity particle confinement compared with flat density profile discharges ($\eta > 1$).

These related changes of the bulk energy and particle transport properties point towards a common change of the transport coefficients and may be interpreted in terms of a generalized non-diagonal model of particle and energy transport connecting the fluxes with the driving thermodynamic forces, namely the gradients of pressure (p) and temperature(T). Using such a model we look for a consistent set of transport coefficients in the different confinement regimes on ASDEX taking the fluxes from radial particle and power balance analysis using the TRANSP code. The numerical procedure to calculate the coefficients and results for L- and H-mode discharges are presented in this paper.

2. Transport equations and numerical procedure

Using non-equilibrium thermodynamics linear relations between the fluxes of particles (Γ_p) and energy (Q) and the true thermodynamic forces, i.e. the gradients of 1/T and μ/T for both electrons and ions (with the chemical potential μ), can be derived satisfying the Onsager symmetry for the off-diagonal coefficients. Subtracting the convective energy flux from the total energy flux Q to get the conductive heat flux $q = Q - 2.5\,kT\,\Gamma_p$ and normalizing the energy flux equation by kT one obtains relations between Γ_p, $\Gamma_{q,e}$ and $\Gamma_{q,i}$ ($\Gamma_q = q/kT$) and the recalculated forces ($\nabla T_e / T_e$, $(1+T_i / T_e)\,\nabla p/p$ and $(T_i / T_e)\,\nabla p_i/p_i$) still satisfying the Onsager symmetry for off-diagonal coefficients. Assuming $n_i = n_e$, $T_i = T_e$ and a plausible relation between off-diagonal elements the following radial electron transport model results

$$\begin{aligned} \Gamma_p &= n\,D(1+\eta)(-\nabla n/n) - n\,\alpha(-\nabla T/T) \\ \Gamma_q &= -n\,\alpha(1+\eta)(-\nabla n/n) + n\,\chi(-\nabla T/T), \qquad \leftarrow \; -\nabla p/p = (1+\eta)(-\nabla n/n) \qquad (1) \end{aligned}$$