Electron internal transport barriers, rationals and fluctuations in the stellarator TJ-II

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The quasicoherent oscillations were observed in TJ-II plasma with different diagnostic: Heavy Ion Beam Probe (HIBP), 2 ω ECR emission, Langmuir and Mirnov probes. Ehe HIBP diagnostic has allowed to observe the radial structure of these oscillations from the edge to the plasma core regions. The presence/absence of the oscillations in the density profiles depend on magnetic field configurations.(Fig.1)

Electron internal transport barriers (e-ITBs) are commonly observed in electron cyclotron heated (ECH) plasmas in stellarator devices. At a high ECH heating power density, electron temperature profiles are centrally peaked and core electron heat confinement is improved. In CHS, W7-AS and TJ-II a large radial electric field shear is measured [1, 2, 3] accompanied by a reduction of fluctuations [1]. Most of these experimental results support the hypothesis that the mechanism for barrier formation is linked to a bifurcation of the radial electric field E_r while the subsequent reduction of turbulence is due to a sheared E_rxB flow generated by the E_r shear. A comparative study of these transport barriers has been reported in [4]. In addition, the influence of the magnetic topology on e-ITB formation has been experimentally studied in TJ-II and LHD. In TJ-II, a configuration scan has shown that the presence of a low order rational surface (m=3 / n=2) close to the plasma core is a necessary condition for triggering the e-ITB formation [3]. As it has been discussed in [5], the key element to improve heat confinement is a locally strong positive electric field. In some tokamaks, the formation of e-ITB is also affected by the presence of rational surfaces in the q-profile, especially for input powers close to the threshold power. At higher heating powers the formation of e-ITBs is less sensitive to rational surfaces in the q-profile, suggesting that the rational surface modifies the power threshold for barrier formation.

The HIBP diagnostic allows us to characterize carefully the radial structure of plasma modes appearing during the e-ITB formation in the core of stellarator.

The HIBP system installed at TJ-II uses a 200keV Cs^+ ion beam. [6]. By sweeping the primary beam, the plasma potential profile and secondary Cs++ beam current can be measured in the $0.1<\rho<1.0$ plasma area. are measured. Due to the relatively low plasma densities involved in these experiments, the secondary beam current can be considered to be proportional to the local plasma density.

In TJ-II, the formation of e-ITB is triggered by positioning a low order rational surface (3/2 rational) close to the plasma core region. During the e-ITB formation, the plasma potential increases in the plasma core region ($\rho < 0.3$), increasing substantially the radial electric field, and remains almost unchanged at outer radii Quasi-coherent modes with frequencies close to 20 kHz have been identified in the density/potential profiles during the development of e-ITB. These modes are clearly observed in the beam current and, marginally, in the plasma potential. Fig.2 shows the radial profiles of the plasma potential and beam current measured by HIBP at two different time intervals during the discharge in a magnetic configuration having the rational surface 3/2 close to the plasma core. The frequency spectra of these signals are displayed in figures 2b and 1c. The coherent mode is localized within the hollow part of the beam current profile measured at 1115 ms and appears also, thought not so clearly, in the plasma potential. This is the plasma region where core E_rxB sheared flows develop at the e-ITB formation. This can be seen in the plasma potential profile measured at 1075 ms. In agreement with previous results, the radial electric field increases (in the range 5 kV/m) during the e-ITB [3]. It is also observed that the formation of the barrier is accompanied by a strong reduction (even disappearance) of the mode.

Electron temperature as measured by the Electron Cyclotron Emission (ECE) diagnostic also increases in the plasma core. The increase in the central temperature depends on the plasma density and ranges from 40% (at low densities $<n_e> \approx 0.5\ 10^{19}\ m^{-3}$) to 20% (at higher densities $<n_e> \approx 0.8\ 10^{19}\ m^{-3}$). The combination of measurements obtained using both diagnostics allow us to conclude that, the quasi-coherent modes are found to being localized within the radial range $\rho \approx 0.1 - 0.4$, with maximum amplitude around $\rho \approx 0.25 - 0.35$, close to the foot of the e-ITB. Fig.3 shows the frequency spectra of the beam current measured at three different radial positions (a) $\rho \approx 0.1$, (b) $\rho \approx 0.3$ and (c) $\rho \approx 0.5$ in three discharges with intermittent e-ITB. These measurements show that the amplitude of the mode is high at $\rho \approx 0.3$ and decreases at internal and external radial positions. Experimental finding show a strong correlation between ECE and HIB once the quasi coherent mode is developed (Fig.4).

It is worth remark that the development of a quasi-coherent mode is not indispensable for the e-ITB formation. Same evidences exist in which no oscillation accompanies the formation of e-ITBs in TJ-II.

A magnetic configuration scan shows evidence of quasicoherent oscilations ($\cong$

20kHz) in the plasma edge. When rational surface is located at the edge gradient region (8/5 rational) HIBP shows a strong correlation with the Langmuir and Mirnov probes (Fig.5, 6).

In conclusion, the reported experimental results indicate that the quasi-coherent modes associated to the rational surface that triggers the formation of e-ITBs in TJ-II are modified by the electric fields developed at the transition. These results show the importance of ExB flows in the evolution of MHD instabilities. Present findings suggest the importance of clarifying the role of electric fields and sheared flows in the stability of MHD modes (e.g. tearing modes) in fusion plasmas.

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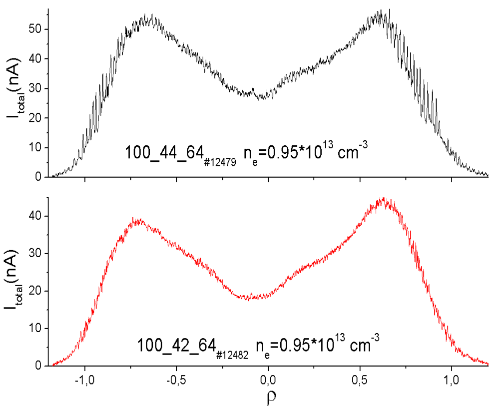

Fig.1 Cs2+ current (electron density) profiles versus magnetic configuration

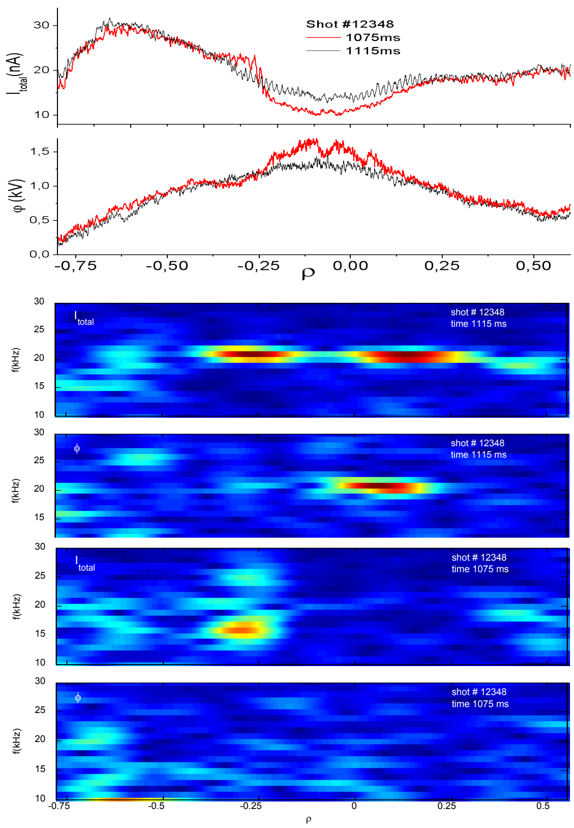

Fig. 2 Plasma potential and HIBP beam current measured without (black) and with (re electron-Internal transport barrier, spectra of the plasma density (upper figures) and potential (lower figures) oscillations before an after e-ITB.

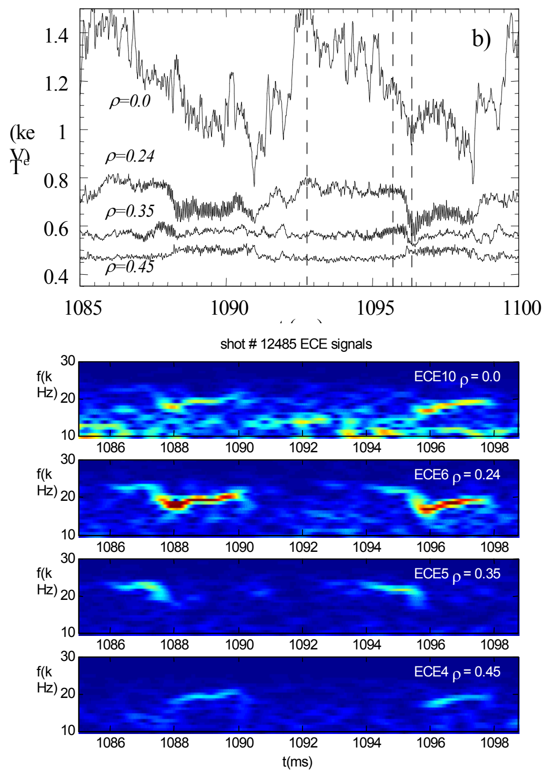

Fig. 3. Time evolution of the electron temperature (ECE) in a plasma with e-ITB formation at 1092 – 1095 ms. Lower boxes – time evolution of the T_e frequency spectra for various ρ.

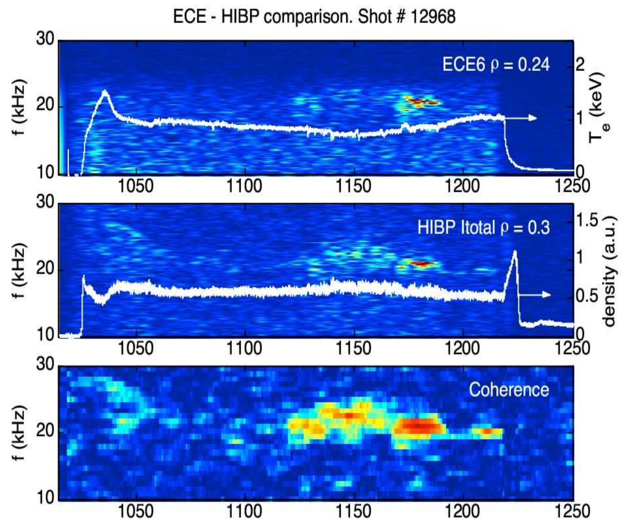

Fig. 4. Comparison HIBP and ECE signals:

(a) ECE evolution and spectrum at ρ ≈ 0.24,

(b) HIBP Cs^{2+} current and spectrum at ρ ≈ 0.3

(c) coherence between them.

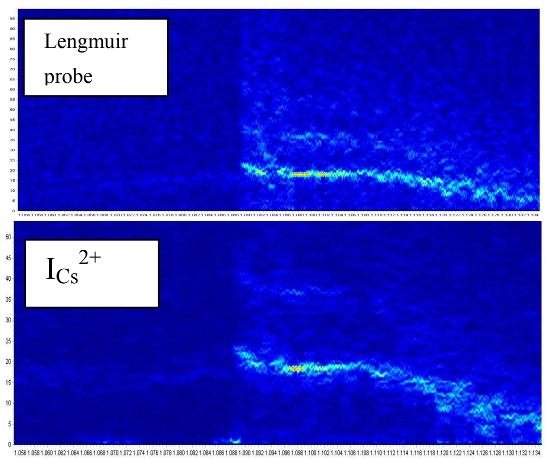

Fig. 5. Correlation between HIBP and Langmuir probes

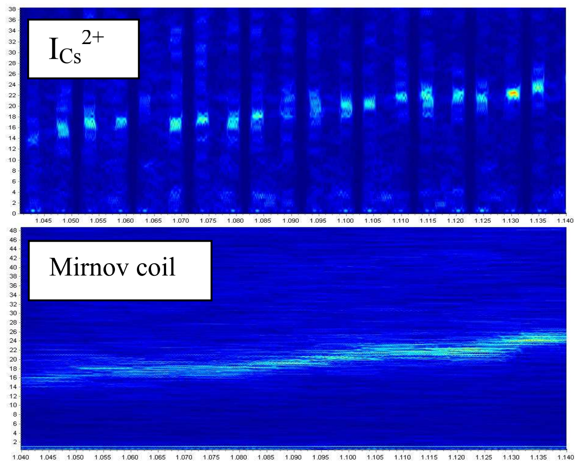

Fig. 6. Correlation between HIBP and Mirnov coils