Radial electric fields and confinement in the TJ-II stellarator

L. Krupnik(1), A. Alonso(2), A. Chmyga(1), N.B Dreval(1),G.N. Dezgko(1), L. Eliseev(3), C. Hidalgo(2),S.M. Khrebtov(1), A.D. Komarov(1), A.S. Kozachok(1), A.V.Melnikov(3), M.A. Pedrosa(2), J. L. de Pablos(2),V.I. Tereshin(1)

(1) Institute of Plasma Physics, NSC KIPT, 310108 Kharkov, Ukraine
(2) Laboratorio Nacional de Fusión. EURATOM-CIEMAT, 28040 Madrid, Spain
(3) Institute of Nuclear Fusion, RRC Kurchatov Institute, Moscow, Russia

I. Introduction

Radial electric fields play a key role on plasma turbulence and confinement in magnetic confined fusion devices. The best performance of fusion devices has been obtained in plasma regimes where ExB shear stabilizing mechanisms are likely to play a role. In stellarator devices, the modification of particle orbits by radial electric fields can also strongly affect neoclassical transport.

The TJ-II stellarator is equipped with a Heavy Ion Beam diagnostic which allows to measure, both with time and spatial resolution, plasma density and potential profiles in the whole TJ-II plasma. This paper reports recent results dealing with the influence of plasma heating and biasing on plasma potential in the TJ-II stellarator.

II. ECRH modulation experiments and potential profiles

Previous experiments have shown that the potential increases up to 1 kV near the magnetic axis in ECRH low-density plasmas ($n_e < 8 \times 10^{18}$ m^{-3}). The secondary (Cs^{2+}) ion current profiles, which directly reflect the plasma density, are hollow. Recently, the impact of ECRH heating power on plasma potential profiles has been investigated by means of the HIBP system. In the present experimental set-up one gyrotron line (L1) provides a continuous heating (200 kW) whereas the second line (L2) is modulated with 100 ms period.

Figure 1 shows the time evolution of heating power (L2), plasma density and plasma potential and secondary Cs^{2+} ion profiles. Global plasma density decreases as ECRH power increases whereas plasma potential become more positive. Interestingly density profiles (as measured by the HIBP system) become more hollow. This behaviour can be a manifestation (or at least is consistent) of the outward particle flux induced by ECRH [1].

Figure 2 shows the time decay of plasma potential ($\rho \sim 0.2$) after ECRH is turned off.

Plasma potential changes about 200 V in a time scale of 100 μs.

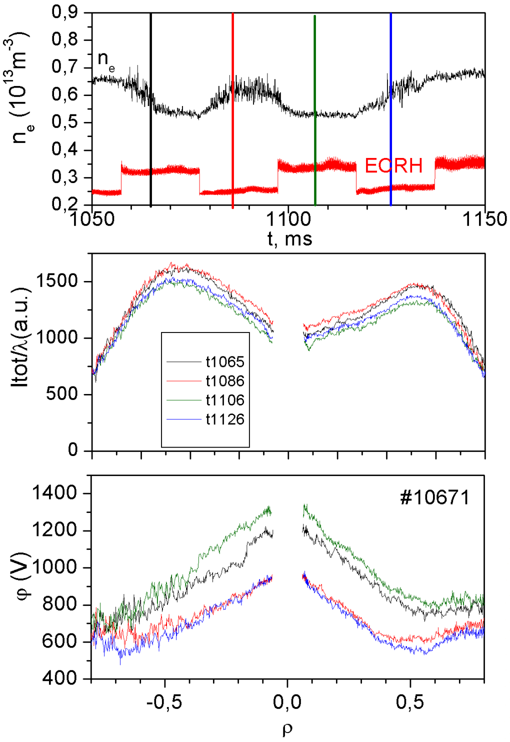

Fig.1. Influence of ECRH heating on HIBP profiles.

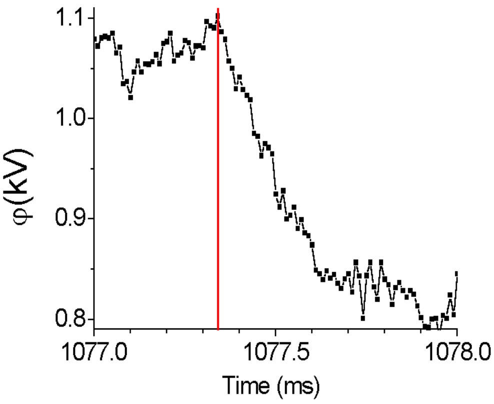

Fig.2. Time decay of plasma potential after ECRH (L2) is turned off.

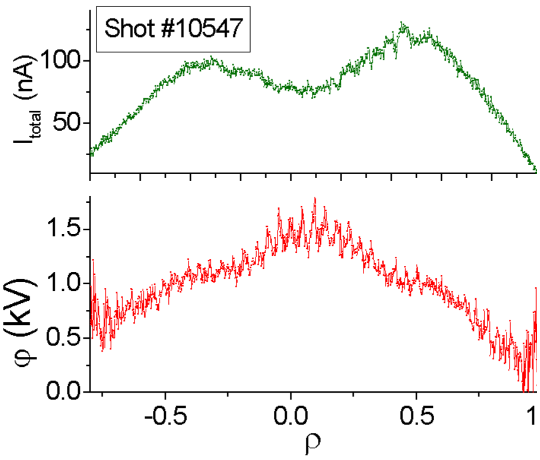

Fig.3. Influence of ECRH modulation (5 KHz) on HIBP profiles.

In addition, ECRH power modulation experiments have proven to be a powerful method to investigate the transport properties in fusion plasmas. This method has been recently used to estimate heat diffusivities and power deposition profiles in the TJ-II stellarator based on the measurement of the amplitude of the electron temperature perturbation induced by ECRH. Those results have shown that the power deposition profile is much wider than those estimated from ray tracing calculations [1].

The spatial localization of the HIBP system allows to characterise simultaneously both the ECRH modulation perturbation in plasma potential and density. As expected, the induced perturbation is much higher in the plasma potential than in the plasma density. Furthermore, the perturbation in plasma potential becomes more localized as plasma density increases (Figure 3). This result is consistent with the possible role of fast transport events (such as those due to electron suprathermal effects) on the power profiles in TJ-II, [1,2].

As ECRH heating power increases the level of density fluctuations (as measured from the Cs^{2+} signals) show an increase in the rms value. Similar results were obtained with edge probe diagnostic.

III. HIBP potential measurements in NBI plasmas

First experiments with Neutral Beam Injection (NBI) heated plasmas have been performed. Flattened core electron temperatures in the range 200 to 300 eV and bell-shaped density profiles with $n_0 \leq 5x1019\ m^{-3}$ are achieved in NBI plasmas (200 kW). In comparison, TJ-II ECRH (200–400 kW) plasmas show hollow density profiles with steep temperature profiles. The time evolution of plasma potential during the transition from ECRH to NBI regimes has been measured (Figure 4). Plasma profiles of plasma potential during ECRH and NBI regime are shown in Figure 5. Core plasma potential decreases (i.e. becomes less positive) after NBI is switched-on. This drop takes place in a milliseconds time scale in the NBI regime once ECRH heating power is switched-off. The total potential variation is the range $\Delta\varphi \sim$ -1000V. In combined ECRH (off-axis) plus NBI regimes plasma potential decreases slowly as plasma density increases.

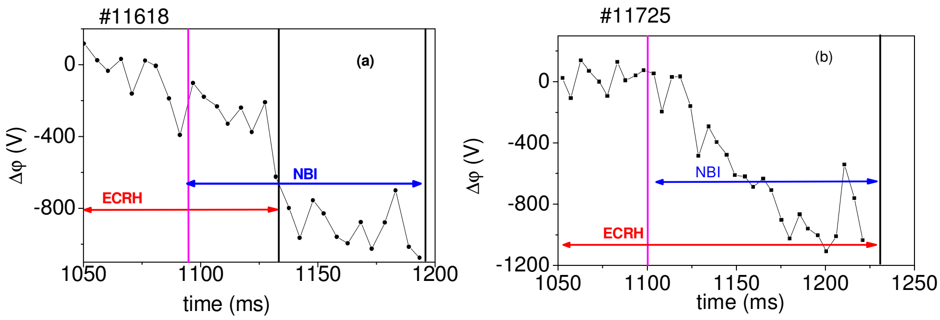

Fig 4: The time evolution of plasma potential during the transition from ECRH to NBI regimes. (a) ECRH on axis (b) ECRH off-axis

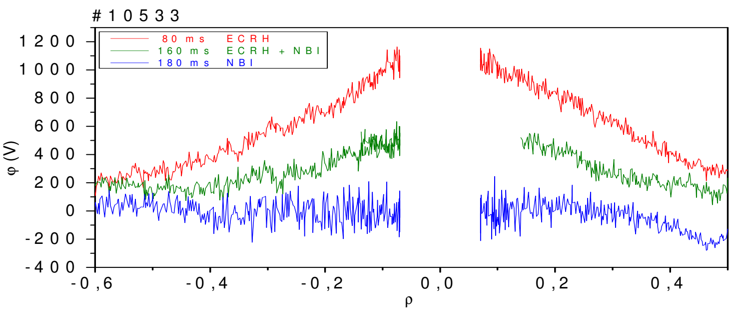

Fig.5: Radial profiles of plasma potential (ECRH + NBI)

Evidence of negative plasma potential has been observed at the final phase of NBI (i.e. at densities of about 3 x 1019 m^{-3}).

IV. Electric fields and confinement

Experiments in TJ-II have shown that it is possible to modify the global confinement and edge plasma parameters with limiter biasing, illustrating the direct impact of radial electric fields on TJ-II confinement properties [4, 5]. Radial electric fields are mainly modified in the proximity of the biased limiter, but the plasma potential in the whole plasma is affected. Significant and minor reductions in ExB turbulent transport has been observed in the plasma edge region. Recently a comparison between two independent diagnostics the HIBP and probes measurements has shown that the modification of ExB turbulent transport (measured by probes near ρ ~ 0.9) is very well correlated with the evolution of plasma potential (measured at ρ ~ 0.9), Figure 6. Biasing is turn on at 1150 ms, however turbulent transport reduction takes place 10 ms latter when a significant drop is observed in edge plasma potential. This result show evidence of electric field induced improved confinement in the TJ-II stellarator.

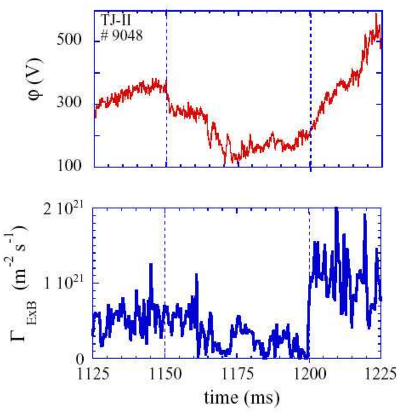

Fig.6. Time evolution of edge plasma potential (ρ ~ 0.8) measured by the HIBP system and the ExB turbulent transport measured by probes (ρ ~ 0.9) during limiter biasing experiments (V_b = 200 V).

Acknowledgment

This work has been partially supported by INTAS project reference 01-0593.

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