PLASMA POTENTIAL MEASUREMENTS BY HEAVY ION BEAM PROBE IN THE TJ-II STELLARATOR

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1. Introduction.

The advantage of HIBP system on TJ-II consists of the simultaneous utilization of two detectors for the secondary ions: a 30º Proca-Green electrostatic energy analyzer and a multiple cell array detector (MCAD) [1]. During operation with electrostatic energy analyzer the sample (ionisation) volume position is controlled by changing the entrance angle of the primary beam to the plasma, using electrostatic sweep plates. The trajectory of primary beam inside the plasma arranges a sequence of the sample volumes for MCAD. The operation with two detectors allows enlarging the number of the sample volumes inside the plasma to obtain plasma profiles and their fluctuations. The HIBP installation in the TJ-II device is composed of three main parts: injection system, detectors and control and data acquisition system. Experiments described in this paper were carried out using the electrostatic energy analyser to measure plasma potential profiles.

2. The TJ-II electrostatic energy analyser

The relation of the plasma potential using a 30º Poca-Green electrostatic energy analyzer with the split plate detector signals is given by the expression [2]:

$$\Phi_{pl} = 2U_a(\delta iF + G_a) - U_b \qquad (1)$$

where U_b and U_a are the accelerator and analyzer voltages, $\delta i = (i_t - i_b)/(i_t + i_b)$ is the normalised difference of the currents on the top (i_t) and bottom (i_b) detector plates, G_a and F are the analyzer gain and dynamic coefficients, respectively, which depend on the analyzer geometry and on the beam entrance angle.

The analyzer built for the TJ-II HIBP has no guard rings. Therefore, a high uniformity of the electric field inside analyser (better than 10^{-4} at the midplane) is achieved with special configurations of the top HV electrode and grounded shield. A manual control of the split detector position allows us to adjust the geometric parameters of the analyzer, thus to modify and optimise the gain G_a. To minimize the errors due to geometrical uncertainties, we used G_a coefficient values obtained in the experiments with He gas puffing after the TJ-II gyrotron pulse. This technique gives the possibility to get the potential reference curve (i.e. to extract the analyzer gain function G angular dependence) after each shot.

3. Radial profiles of plasma potential measurements and influence of plasma density.

Plasma potential profiles have been investigated in a sequence of different configurations in ECRH plasmas (P_{ECRH} = 300 kW, n = 0.5 – 1.1 x 10^{13} cm^{-3}). In the TJ-II stellarator, [3] the magnetic configuration is generated by a system of toroidal, central, poloidal and vertical coils. The configuration labels refer to the currents flowing in three of the four sets of coils (Central Circular, Central Helical and Vertical Field coils).

Radial profiles of the plasma potential near the magnetic axis show that the potential increases up to 1 kV near the magnetic axis (i.e. positive radial electric fields) in low density plasmas (n < 8 x 10^{13} cm^{-3}) (Fig. 1). The secondary ion density (Cs^{++}) profiles are hollow in good agreement with Thomson density profiles. However, plasma potential profiles show a dependence with plasma density. Whereas positive radial electric fields have been observed at low ECRH density plasmas (n < 10^{-13} cm^{-3}) at higher densities negative radial electric fields have been measured (Fig. 2).

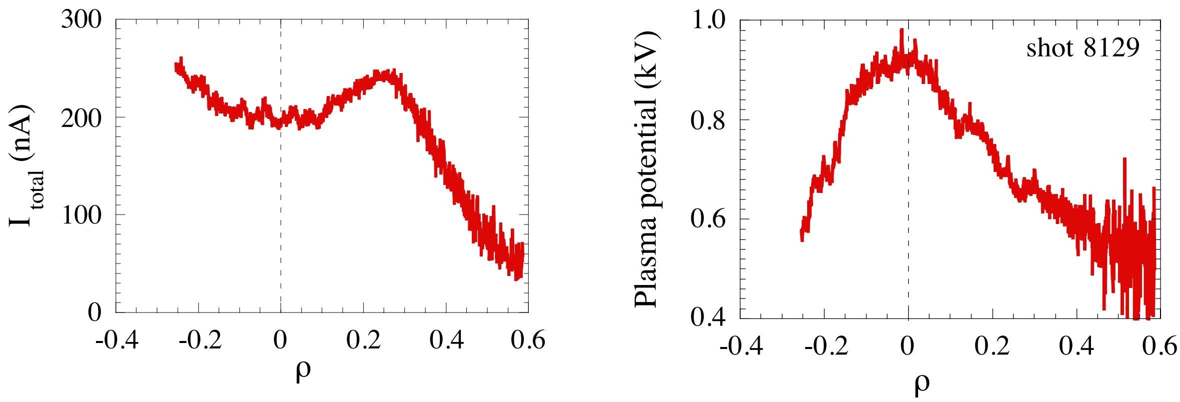

Fig. 1 Plasma profiles near the magnetic axis in the plasma configuration 100_28_58 (n =0.6 x 10^{13} cm^{-3}).

5. Radial electric fields and neoclassical calculations

The neoclassical transport estimations performed for low collisionality ECRH plasmas show that, because of the different ion / electron temperatures, the electron particle fluxes usually exceed their ion counterparts, thus driving a relatively large radial electric field to maintain ambipolarity [4]. This electric field partially compensates the quite different diffusions of electrons and ions.

In simulations carried out in low density plasmas the resulting radial electric field is positive (about 100 V/m), thus reducing mainly the electron particle and energy fluxes. The positive values of the radial electric field (50 V/ m) measured by the HIBP system at low density plasmas are of the order of the neoclassical estimations (Fig. 2).

6. Fluctution studies

Radially localized bursts in plasma potential fluctuations have been observed with frequencies in the range 10 – 40 kHz. In particular, a correlation between HIBP and mirnov signals have been found a some radial locations and frequencies (10 - 20 kHz) (Fig. 3). The rms value of HIBP fluctuations increases in the proximity of the radial location where the correlation hibp-mirnov is maximum. Furthermore, the radial location where HIBP and Mirnov signals shows the maximum correlation depends on the magnetic configuration. These findings can be explained on the basis of MHD fluctuations linked to low order rational surfaces. The investigation of the radial structure of the plasma potential in the proximity of rational surfaces is at present under investigation.

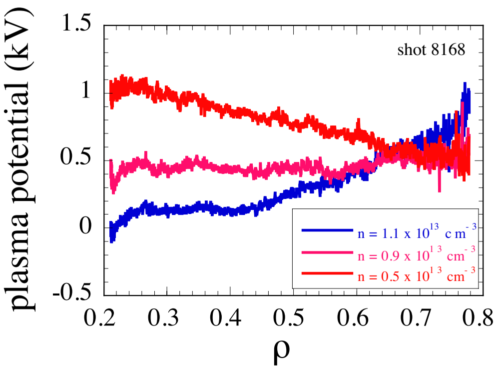

Fig. 2 Influence of plasma density in plasma potential profiles (configuration 100_38_62).

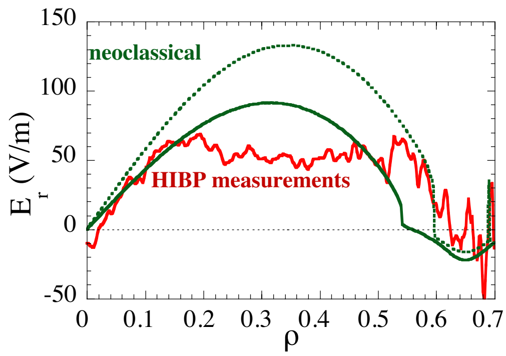

Fig. 3 Comparative studies of radial electric fields from neoclassical predictions and HIBP results.

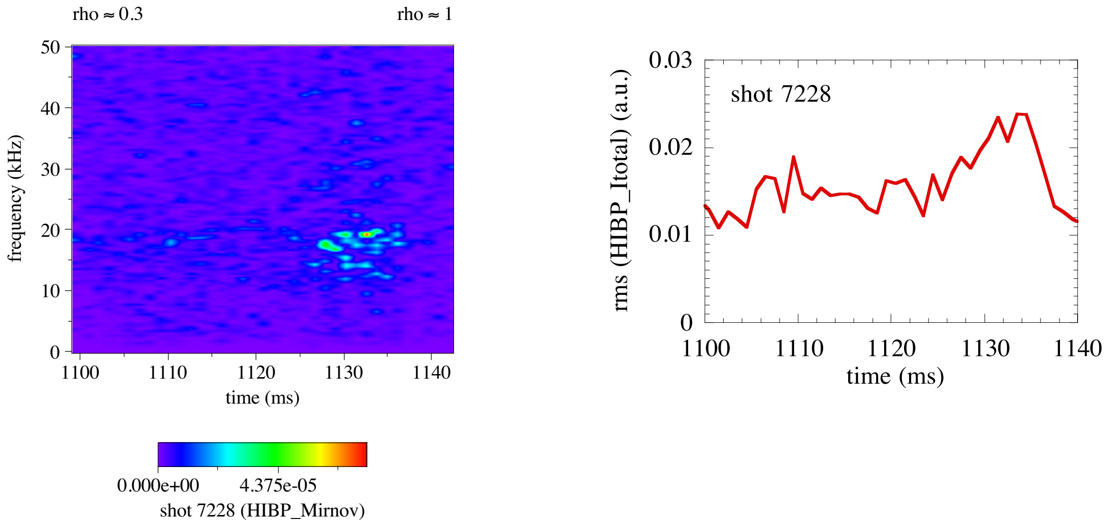

Fig. 4 Correlation between fluctuations in HIBP and Mirnov signals and radial profiles of fluctuations (configuration 32_102_65).

7. Conclusions

First radial profiles of plasma potential have been obtained in the TJ-II stellarator by the HIBP diagnostic. At low density plasmas positive radial electric fields measured in the plasma core region are consistent with neoclassical estimations. Furthermore, the radial electric fields show a strong dependence with plasma density.

An important improvement in the signal to noise ratio allows the measurements of plasma potential fluctuations in the TJ-II stellarator. Radially localized bursts in plasma potential fluctuations correlated with Mirnov signals, which can be related to the presence of rational surfaces, have been observed.

The HIBP system already in operation in the TJ-II stellarator will play a key role to clarify the importance of low-order rationals in the generation of radial electric fields and transport barriers in fusion plasmas.

References.

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