RECENT MEASUREMENTS OF THE ELECTRIC POTENTIAL PROFILE AND FLUCTUATIONS IN ECRH AND NBI PLASMAS ON TJ-II STELLARATOR

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Heavy Ion Beam Probe diagnostics is used in TJ-II stellarator to study directly the plasma electric potential with a good spatial (up to 1cm) and temporal (up to 2 μs) resolution. Low density (n_e = (0.3…0.5)×10^{19} m^{-3}) ECRH plasma in TJ-II is characterized by positive plasma potential (φ(0) = +600…+ 400 V). At higher densities the minor area of the negative electric potential appears at the edge. This area increases with the density, finally makes potential fully negative. This tendency is affected by ECRH power and deposition area. The NBI plasmas are characterized by negative electric potential in the full plasma column from the center to the edge, (φ(0) = -300…-600 V). These results show the clear link between plasma potential, temperature, density and particle confinement.

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1. INTRODUCTION

The studies of E_r or plasma potential are very important for understanding of the mechanisms to the confinement improvement regimes in toroidal plasmas. The task is difficult, because there are still many plasma parameters, which give the impact to the core E_r formation. This paper presents an attempt to characterise mean core plasma potential for ECRH and NBI heated plasmas of TJ-II stellarator. Also the study of E_r effect on plasma turbulence as a fluctuation suppression factor is very important. It is possible to measure Alfven modes, their spatial distribution and characteristics inside plasma bulk.

2. TJ-II STELLARATOR

TJ-II is a four-field-period low-magnetic shear stellarator. Major radius is <R> = 1.5 m, minor is <a> = 0.22 m. The toroidal field strength is B_0 = 1.0 T. The mean density obtained so far $\langle n_e \rangle$= (0.3…7.0)x$10^{19}$$m^{-3}$.

The plasma is headed by 2 gyrotrons with maximum power 2x300=600 kW. Also 2 neutral beam injectors with maximum heating power 2x500=1000 kW is installed.

TJ-II is equipped by various diagnostics: Thompson scattering, Electron Cyclotron Emission diagnostic, Langmuir probes, Heavy Ion Beam Probe, and etc.

3. HIBP ON TJ-II

TJ-II is equipped with a 125 keV Cs^+ HIBP [1], which allows us to obtain plasma profiles from the edge to the core each 5…20 ms (Fig. 1). Those are **φ** - plasma electric potential from the energy deviation of the probing particles, $\mathbf{n_e}$ - plasma electron density from the total beam current of secondary Cs^{++} ions. **φ** and $\mathbf{n_e}$ fluctuations are also can be analyzed up to 250 kHz so far.

4. PLASMA POTENTIAL EVOLUTION

In the experiments, the different type of ramp up of the density due to gas puffing control and ECRH to NBI phase explored. We can see that transition from the positive to negative electric potential/E_r is quite smooth. (Fig. 2). Low (almost zero) potential/E_r happens when the mean density is in the range of n_e ~ 1×10^{19} m^{-3}. We can see no link with the mean of heating scenarios, but the clear potential - density link (Fig. 3).

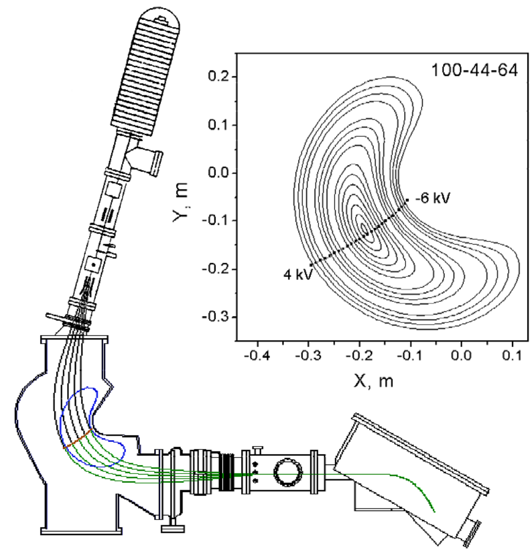

Fig.1. HIBP diagnostic installation and commonly used detector line for a standard operational regime

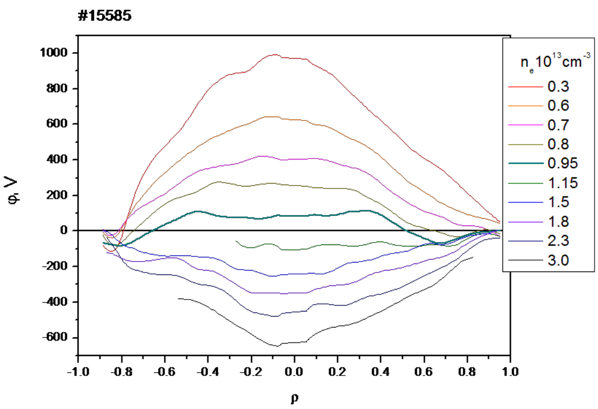

Fig.2. Transition of the potential profiles

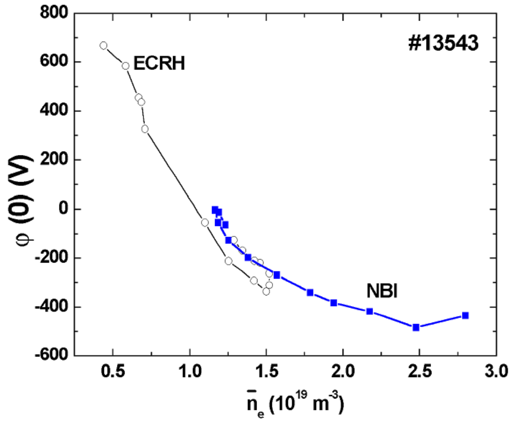

Fig.3. Potential-density behavior

5. POWER DIPOSITION LEVEL VERSUS POTENTIAL

The experiments with modulation of the gyrotron power have been performed. We try to investigate potential profiles versus heating power at constant density. The scans was extracted at different shots depending on the ramp up of the density around $n_e = 0.65 \times 10^{19}$ m^{-3} with error of $\pm 0.2 \times 10^{19}$ m^{-3}. The resulting picture is shown in Fig.4. It can bee seen clear evolution of the potential profile versus power level of the gyrotrons. Plasma potential value rises with power growth [2].

In order to understand the correlation between central potential and electron temperature, as it linked to the heating power, we try to compare the signal from central measuring point of HIBP at ρ = 0.08 with the calibrated signal of Electron Cyclotron Emission diagnostic (ECE9). The results are shown in Fig. 5. There is also almost linear dependence of temperature on central potential with some deviation.

6. E_r PROFILE EVOLUTION WITH DENSITY RISE

During the operation of the TJ-II using two neutral beam injectors (NBI1 and NBI2) which produced high plasma density the poloidal rotation can reach 10 km/s. It corresponds to the electric field of 100 V/cm (Fig. 6).

Up to now, it is not possible to access the plasma at the central area and especially "hardcore" zone at the plasma densities more than 5×10^{19} m^{-3} because of significant primary beam attenuation. But we are able to measure the electric field at the "softcore" periphery even at the higher densities.

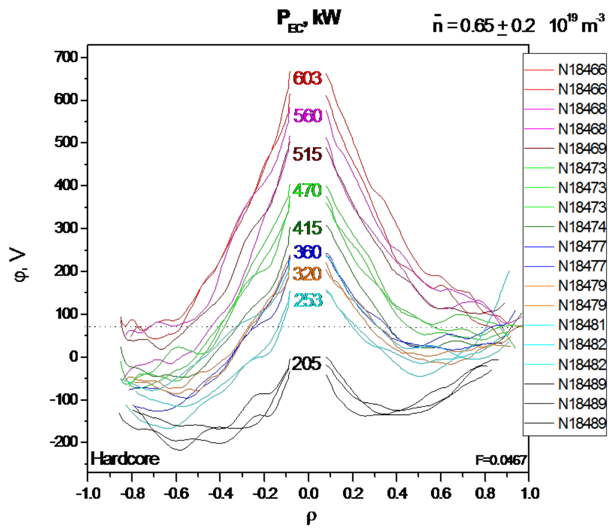

Fig.4. ECRH power scan

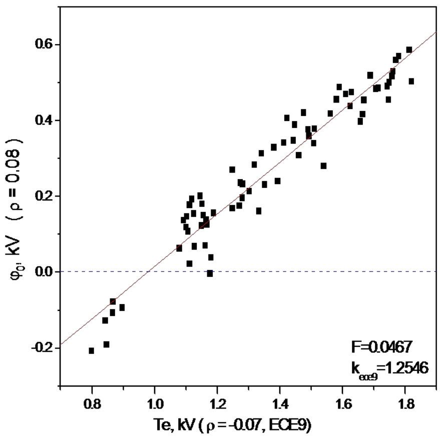

Fig.5. Potential versus temperature

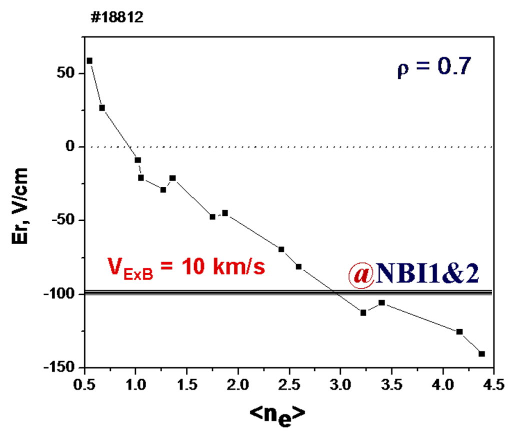

Fig.6. Measured values of the radial electric field at the periphery

In nearest future it is planned new injector system with increased primary current, which will give deeper measuring zone.

7. PLASMA TURBULENCE

Density fluctuation level is sensitive to $<n_e>$, and it suppressed at NBI (Fig. 7).

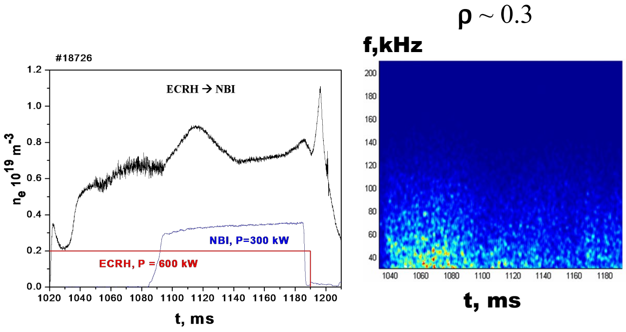

Fig.7

8. ALFVEN MODE OBSERVATION

In special regimes the Alfven modes were observed (Fig. 8).

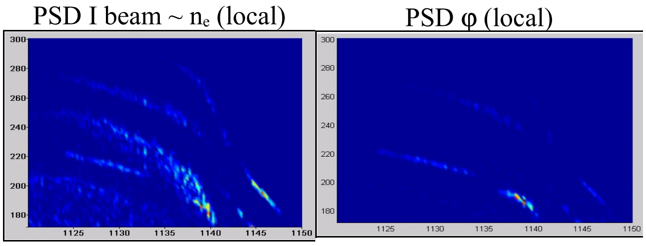

Fig.8. Power signal densities (PSD) of the total secondary current and potential

Using spectrum and correlation analysis, it will be possible to determine the nature and the position of the exciting Alfven modes in the plasma and to make crosscheck with other diagnostics.

CONCLUSIONS

The recent HIBP study of ECE and NBI regimes in TJ-II plasma shows the evidence of positive electric potential up to +1300 V in the low density ECRH plasma and of negative electric potential up to -600 V in the high density NBI heated plasma. The $<n_e>$ and φ(0) are in inverse correlation: the higher density leads to the lower plasma potential at the core and at the edge. The $T_e(0)$ and φ(0) have a direct dependence: the higher T_e – the higher φ(0). With density rise, E_r evolves from positive to negative values. Further negative E_r increases at the gradient region. Density rise is associated with the suppression of the plasma turbulence. HIBP is a powerful instrument to study spatial distribution and properties of the Alfven modes inside plasma.

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ПОСЛЕДНИЕ РЕЗУЛЬТАТЫ ИЗМЕРЕНИЯ ПРОФИЛЯ ПОТЕНЦИАЛА И ФЛУКТУАЦИЙ ПРИ НАГРЕВЕ ЭЦР И ПУЧКОМ НЕЙТРАЛОВ В ПЛАЗМЕ НА СТЕЛЛАРАТОРЕ TJ-II

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Диагностика плазмы тяжелым пучком ионов используется на стеллараторе TJ-II для бесконтактного измерения электрического потенциала плазмы с высоким пространственным (до 1 см) и временным (до 2 мкс) разрешением. Плазма с низкой плотностью ($n_e = (0.3…0.5)×10^{19}$ $м^{-3}$) при ЭЦР- нагреве в TJ-II характеризуется положительным потенциалом (φ(0) = +600…+400 В). При больших плотностях небольшая область с отрицательным потенциалом возникает на периферии. Эта область увеличивается с возрастанием плотности и, в конечном итоге, потенциал плазмы становится полностью отрицательным. Такое поведение зависит от мощности ЭЦР-нагрева и области высвобождения мощности. Плазма при нагреве нейтральным пучком характеризуется отрицательным потенциалом всего плазменного шнура от центра к периферии (φ(0) = -300…-600 V). Эти результаты показывают четкую связь между потенциалом плазмы, электронной температурой, плотностью и удержанием частиц.

ОСТАННІ РЕЗУЛЬТАТИ ПО ВИМІРУ ПРОФІЛЮ ПОТЕНЦІАЛУ ТА ФЛУКТУАЦІЙ ПІД ЧАС НАГРІВУ ЕЦР ТА ПУЧКОМ НЕЙТРАЛІВ У ПЛАЗМІ НА СТЕЛАРАТОРІ TJ-II

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Діагностика плазми за допомогою пучка важких іонів використовується на стелараторі TJ-II для безконтактного вимірювання електричного потенціалу плазми з високою просторовою (до 1 см) та часовою (до 2 мкс) здатністю. Плазма з низькою щільністю ($n_e=(0.3…0.5)×10^{19}$ $м^{-3}$) в ЕЦР-режимі нагріву на TJ-II характеризується позитивним потенціалом (φ(0) = +600…+400 В). При більшій щільності невелика область з негативним потенціалом виникає на периферії. Ця область зростає із збільшенням щільності і, зрештою, потенціал стає повністю негативним. Така поведінка залежить від потужності ЕЦР-нагріву і області її вивільнення. Плазма під час нагріву нейтральним пучком характеризується негативним потенціалом всього плазмового шнура від центру до периферії (φ(0) = -300…-600 В). Ці результати показують чіткий зв'язок між потенціалом плазми, електронною температурою, щільністю та утриманням часток.