Contribution ID: **680** Type: **Regular Poster**

2D distributions of potential and density mean-values and oscillations in the ECRH and NBI plasmas at the TJ-II stellarator

Thursday 13 May 2021 18:20 (20 minutes)

Both mean and oscillatory components of radial electric field Er play important roles in the formation of the turbulent and transport processes in toroidal devices, tokamaks and stellarators. Previous experiments [1, 2] and gyrokinetic modeling [3] have shown that the electrostatic potential φ (and Er) may vary along the flux surfaces that may affect the transport. In addition to the collisional neoclassical mechanisms, electrostatic turbulence may affect strongly the radial transport in some regions of stellarator plasmas. On top of that, the shear of ExB flow may suppress the turbulence and improve the plasma confinement. Therefore, measurements of 2D distributions of mean values and fluctuations for potential φ and density ne may shed a new light to the physical mechanisms of radial transport.
Four basic plasma scenarios were explored with heavy ion beam probe diagnostics in TJ-II. They are (i) low line-averaged density ne=0.45x1019 m-3 plasmas with higher PEC=470 kW (Te(0) = 1.6 keV) and (ii) lower PEC=250 kW (Te(0) = 1.4 keV) on-axis ECR-power, (iii) higher density ne=0.8x1019 m-3 plasmas with lower PEC=220 kW (Te(0) = 1.2 keV) (iv) and high-density ne=1.0-1.2x1019 m-3 co-NBI plasma with PNBI=550 kW (Te(0) = 0.6 keV).
Profiles of potential and density at for scenario (i) and (iii) are shown in Fig. 1. We see that growth of density is accompanied by evolution of the potential shape from conical to "Mexican hat", while the density profiles are flat or slightly hollow. The potential has the positive peak at the ECRH power deposition area and LFS-HFS symmetry. HIBP and Langmiur probe (LP) data (lines and points at Fig. 1(a)) are consistent at the edge, 0.85<ρ<1. For scenario (iv) with high density potential profile is fully negative with a minimum value up to -400 V at the plasma centre.
The poloidal 2D map (Fig. 2a, scenario (i)) shows that the local maximum of potential (up to 1 kV) coincides with the plasma center, and potential contours are consistent with the vacuum magnetic flux surfaces demonstrating the poloidally symmetric structure. Such poloidal symmetry holds for all four explored scenarios.
The contour plot for RMS density fluctuations with (f<300 kHz, k⊠< 3 cm-1) presents a more complicated shape with poloidal anti-ballooning asymmetry, Fig. 2(b). Such poloidal asymmetry holds for both plasma potential and density perturbation for all four explored scenarios. Asymmetry is stronger for low-densities: at the mid-radius, where the density has maximum, RMS φ ~ 15 V at LFS vs ~ 20 V at HFS; RMS δne/ne ~ 2% at LFS vs ~ 3% at HFS, as presented in Fig. 2b, scenario (i). For scenario (i) the level of the potential and density perturbations was about 1.5-2 times higher than for scenario (iii). The lowest level of fluctuation RMS takes place for NBI plasma, scenario (iv).

Plasma density turbulence (f < 150 kHz, k < 3 cm-1) tends to rotate towards ExB drift velocity in ion diamagnetic drift (iDD) direction; Vturb = VExB = 10-15 km/s in low-density plasma in scenario (i). For scenario (ii) the feature is similar with the reduced velocity value. For scenario (iii) with higher densities and Mexican hat potential profile both Vturb and VExB, rotate to iDD in the core and to electron diamagnetic drift (eDD) direction at the edge, but Vturb exceeds VExB. For scenario (iv) with high density NBI plasma and negative monotonic potential profile both Vturb and VExB, rotate to eDD direction at the whole radial interval.
Obtained results show that TJ-II, equipped by the unique set of the diagnostics became a unique platform for validation of theoretical models and gyrokinetic simulations [3], predicting the poloidal symmetry breaking for plasma potential and density turbulence on magnetic flux surfaces in 3D devices.

References
1. Sharma R. et al. 45th EPS Conf. on Plasma Physics (2018) P5.1061.
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3. Sánchez, E. et al. Nucl. Fusion 59 (2019) 076029.

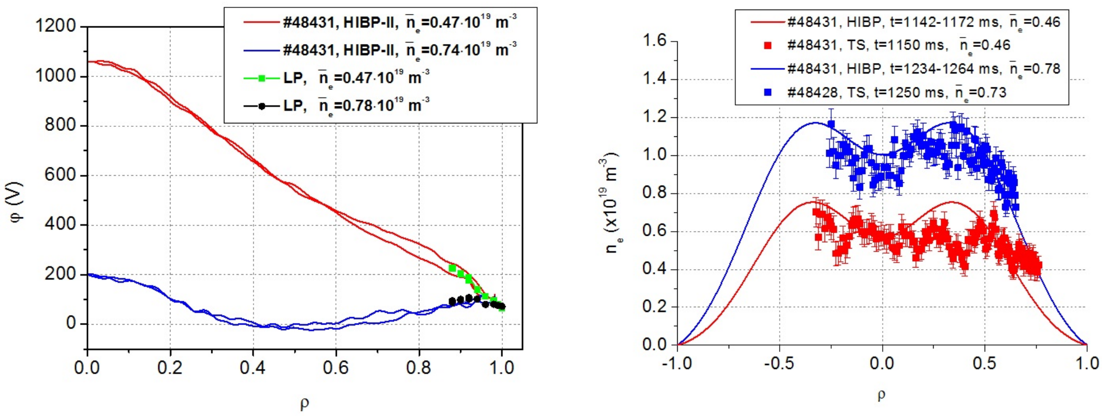

Figure 1: Profiles of potential measured by HIBP (lines) and Langmuir probe (points) –(a), and density measured by HIBP (lines) and Thomson scattering (points) –(b) for scenario(i) –red and (iii) –blue.

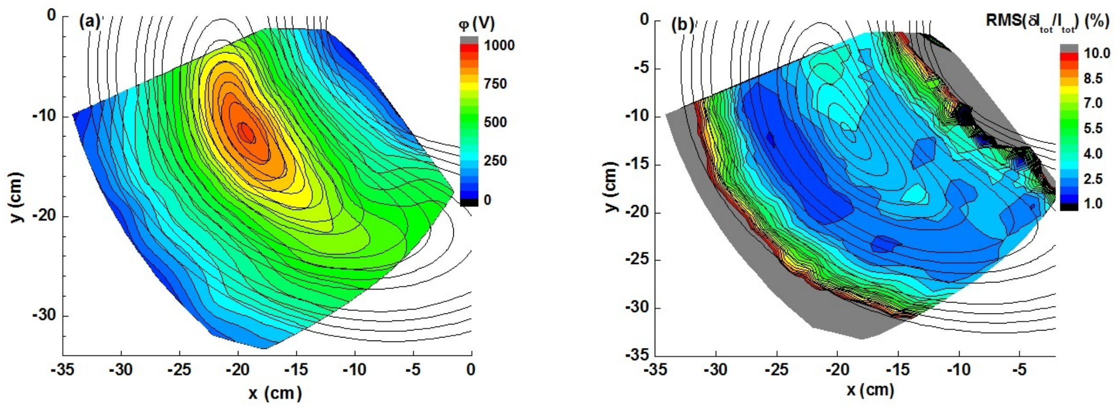

Figure 2: (a) An example of poloidally symmetric 2D map of mean potential in Volts. (b) Anti-ballooning structure of the RMS of density fluctuations in %. Steady-state plasma in scenario(i): ne = 0.45 x 1019 m-3, Te (0) = 1.6 keV).

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Session Classification: P6 Posters 6

Track Classification: Magnetic Fusion Experiments