Heat and particle fluxes estimation method involving measurements of radial electric field by using ball-pen probe array in linear magnetized plasmas

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In the study of plasma turbulence, being able to perform direct measurements of the space potential is indispensable for the evaluation of quantities like heat and particle fluxes in magnetized plasmas. The ball-pen probe (BPP) has been developed and is nowadays widely used to measure the space potential ϕ_s and the electron temperature T_e in high temperature magnetized plasmas [1, 2], together with the classical Langmuir probe (LP).

Application of ball-pen probe in low temperature devices may meet some additional challenges since these are usually equipped with relatively low magnetic fields. BPP working principle is, in fact, based on the difference between the gyro-motion of ions and electrons. Hence, we are conducting a feasibility study of a BPP whose main goal is measuring heat and particle fluxes in the Plasma Assembly for Non-linear Turbulence Analysis (PANTA) linear device. PANTA generates a high-density helicon plasma with an external magnetic field going up to 0.15 T. The BPP was installed at an axial position $z = 1.1$ m from the helicon plasma source, which has a 10 cm diameter.

BPP is designed to reduce the electron saturation current I^-_{sat} detected by the probe until it reaches the ion saturation current I^+_{sat} level by exploiting the difference between the Larmor radii of electrons and ions, such that the floating potential ϕ_f of the BPP eventually reaches the value of the plasma space potential ϕ_s. Furthermore, T_e can be determined by combining the ϕ_f of a BPP and a Langmuir probe (LP), since the relation between the ϕ_s and ϕ_f of an electrostatic probe is given by

$$\phi_s = \phi_f + \alpha T_e, \quad (1)$$

with $\alpha = \ln (I^-_{sat} / I^+_{sat})$ [3].

After properly calibrating the movable-collector depth h with respect to the shielding tube of the probe, the equation (1) should permit the direct measurement of ϕ_s, T_e and their fluctuations in the linear magnetized device PANTA. This also means the radial electric field can be directly measured to evaluate radial heat flux $Q\,(\propto n\,\widetilde{T}_e\widetilde{v}_r)$ and particle flux $\Gamma\,(\propto \tilde{n}\widetilde{v}_r)$ related to different kinds of specific fluctuation modes.

Figure 1 shows the comparison between space potential measurements performed by previously tested BPP and Langmuir probe used as reference diagnostic. Successful measurements were performed by the BPP in the edge and the peripheral region of the plasma. Two new probe arrays were later assembled with different collector and shielding tube diameters to address the mismatching between the BPP and the reference measurements in the plasma core. The Hall parameter $\beta_i = \omega_{ci} / \nu_i$ for the ion, defined as the ratio between the ion cyclotron frequency ω_{ci} and the ion collision frequency ν_i, was in fact very small in the core of PANTA and was identified as an insightful parameter on whether the BPP may need any design correction [4].

Figure 2 shows one of the new probe arrays, characterized by a twin BPP configuration and a middle Langmuir tip. Results obtained with this probe will be presented. The two twin channels are in fact of great importance for radial electric field evaluation, needed to infer the fluctuations-driven heat and particle fluxes leaving the confinement.

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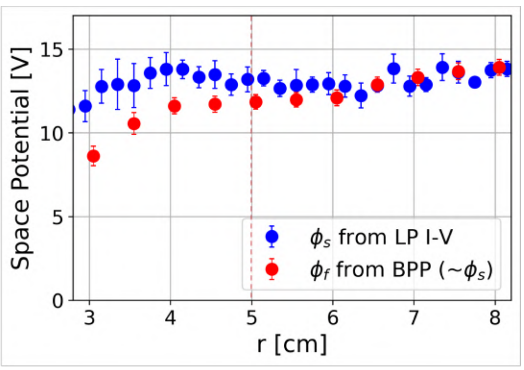

Fig.1 Radial profile of plasma space potential measurements by previous Ball-pen probe (blue) and Langmuir probe (red) in PANTA.

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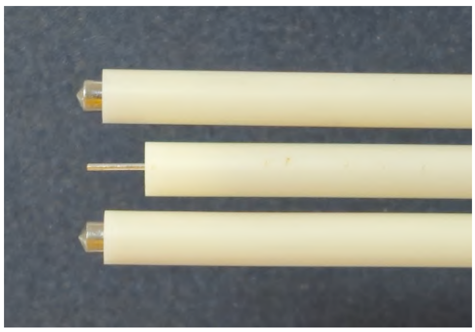

Fig.2 Picture of new Ball-pen probe array installed on the linear device PANTA.