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First experimental results of statistical properties of turbulence plasma fluctuations in the SPLM upgrade

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1. Introduction

Mean cross-field transport of particles and heat in magnetized plasmas is usually found to be far larger than the expected from diffusive transport. This anomalous transport is related to self-similar properties in the probability distribution functions (PDFs) of transported quantities for both fusion and non fusion plasmas [1]. Moreover, comparative studies of plasma turbulence structure in different devices support the view that plasma turbulence displays universality [2,3]. In this context, first experimental results of statistical properties of turbulence plasma fluctuations in the linear device SPLM [4] upgrade (SPLM-up) will be reported. SPLM-up has been constructed to compare turbulence studies with those of fusion plasmas. Plasma profiles of parallel and poloidal flows and fluctuations have been investigated using a Langmuir/Mach probes multi array.

2. Experimental Setup

Plasma is performed in a cylindrical stainless steel vessel with an internal diameter of 0.15 m and a length of 0.92 m that replaces the former cylindrical glass vessel. This new vessel is designed to improve plasma accessibility as well as to enlarge the plasma radial section. It is connected with a circular waveguide with a diameter of 0.08 m and a length of 0.25 m by a stainless steel truncated cone with a length of 0.17 m through an inner circular quartz glass window with a diameter of 0.08 m located at its smaller base. This window seals the mean vessel to keep the vacuum inside. Magnetized plasma is produced by launching longitudinally electromagnetic waves (LMG) with a frequency of 2.45 GHz into the circular waveguide through a turnstyle junction, which polarizes the microwaves in a linear, circular or elliptic manner (both right or left hand sides). Incident power (P_{LMG}) ranges between 0.6 kW and 6 kW. Stationary longitudinal magnetic field can vary between 0.05T

Gas	B (mT)	T_e (eV)	n_e (m^{-3})	λ_D ($\times10^{-6}$m)	ϱ_{Le}($\times10^{-6}$m)	ϱ_{Li}(cm)	f_{ce}(GHz)	f_{ci}(kHz)	f_{pe}(GHz)	f_{pi}(MHz)
He	102	12	4e16	94	81	0.7	2.85	387	2.50	29
Ne	109	8	1e17	51	62	1.2	3.05	83	3.75	20
Ar	121	2.5	9e16	32	31	0.8	3.40	46	3.25	12

Table 1. Typical mean values in SLPM-up

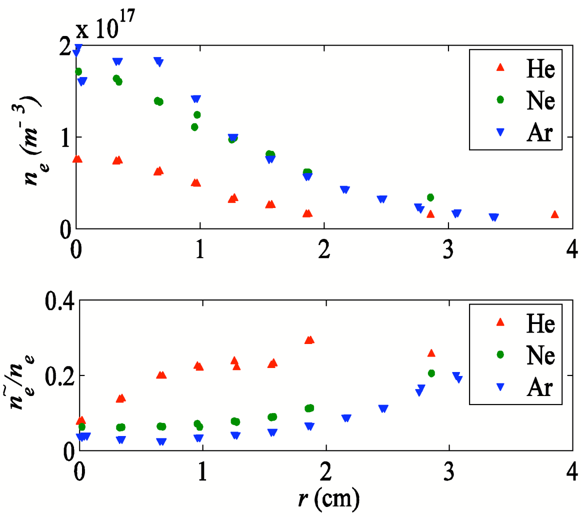

Figure 1. Electron density profiles

and 0.15T and it is generated by six water-cooled coils, which are concentric with the stainless steel vessel and the waveguide. The gas working pressure varies between 10^{-3} and 10^{-1} mbar. This system can operate in a continuous regime. Five windows, with a diameter of 4 cm, are set out along the stainless steel vessel and allow to introduce several diagnostic devices. The mean electron density is determined by an 8 mm interferometer. Langmuir/ Mach probes array consists of one set with 4 tips of 2mm long and 0.5 mm of diameter which provide ion saturation current fluctuations and floating potential fluctuations. Another two probes (in the ion saturation regime) are located along the magnetic field and provide the parallel Mach number. Two more windows (with diameters of 4 and 15 cm, respectively) are sealed with a quartz glass through which visual inspection and high speed imaging of plasma visible light emission techniques will be possible. Fluctuation measurements were digitalized using six fast data acquisition channels with a sampling rate of 1MHz which are connected to the probes and 2×10^5 points per channel are saved with an ADCs resolution of 12 bits.

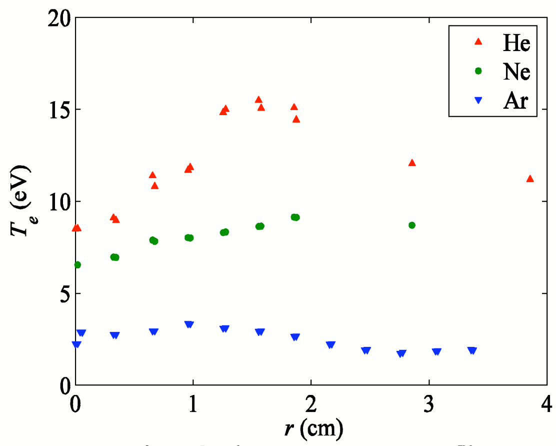

Figure 2. Electron temperature profiles

3. Experimental Results

Electron temperature and density profiles have been measured for helium, neon and argon plasmas under different

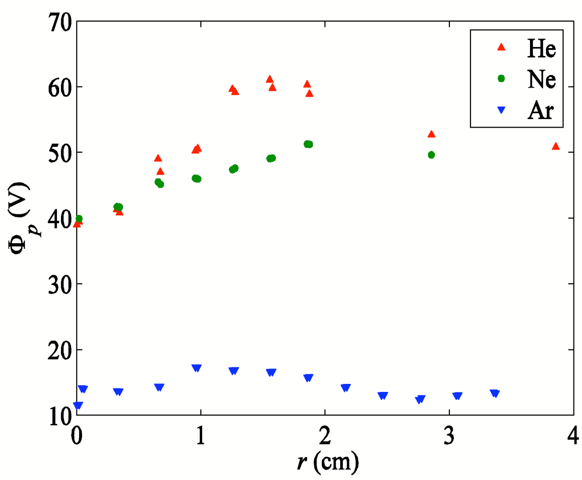

Figure 3. Plasma potential profiles

experimental conditions. Typical plasma parameters in SLPM-up are shown in Table 1. Electron density and temperature profiles are shown in figures 1 and 2, respectively. Electron density typically ranges from 10^{15} m^{-3} to 10^{18} m^{-3} and electron density normalized fluctuations are about 20% (He) or 10% (Ne, Ar) in the inner plasma region, increasing in the outer region (typically below 30%). Electron temperature tipically varies from 2 to 20 eV. Hollow profiles of electron density and temperature have been found in helium plasmas. Plasma potential profile is obtained as $V_p = V_f + \alpha T_e$ where V_f is the floating potential and T_e is the electron temperature and it tipically varies between 40 V and 65 V in the case of He and Ne, and between 0 V and 20 V in the case of Ar (see fig. 3). Plasma radial potential normalized fluctuations are tipically below 25%.

Statistical properties of turbulent fluctuations and turbulent induced fluxes have been investigated for He, Ne and Ar plasmas. Ion saturation current PDFs are rather gaussian (skewness ≈ 0, kurtosis ≈ 3), although fluctuation driven particle flux PDFs are not (see figures 4 and 5). Probability density functions (PDFs) for fluctuation induced fluxes have been estimated under different experimental conditions. In all cases, turbulent fluxes have a non-gaussian behaviour.

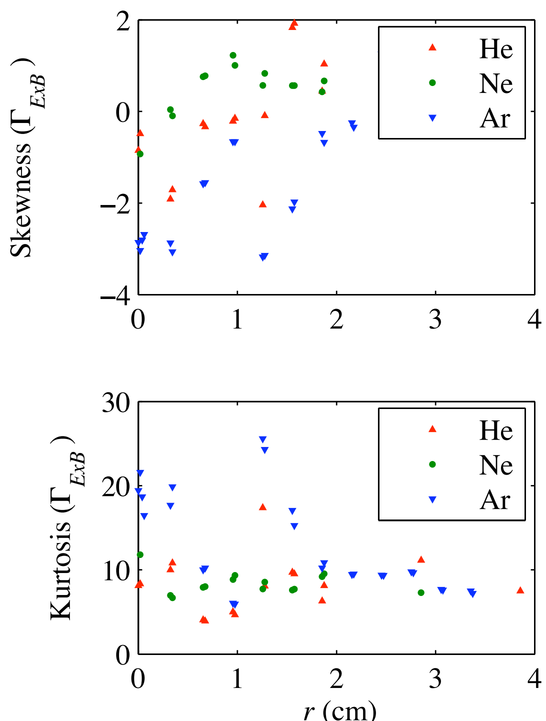

Figure 4. Statistical properties of Γ_{ExB}

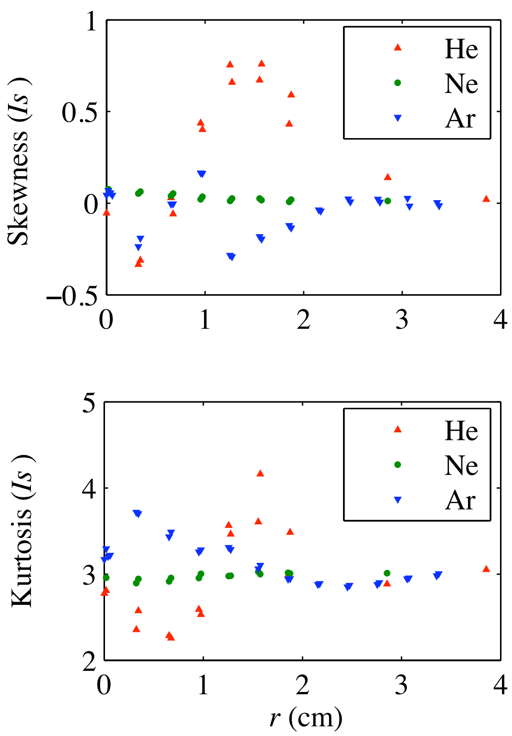

Figure 5. Statistical properties of *Is*

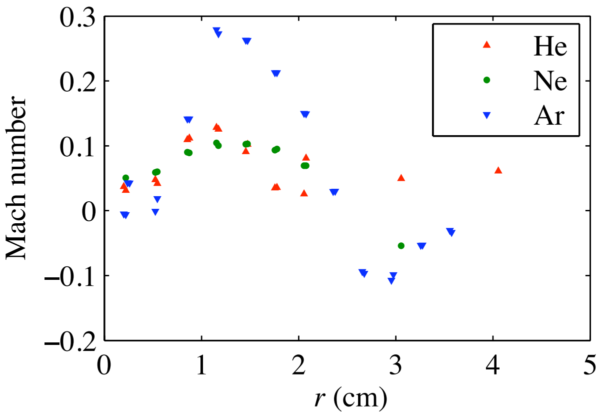

Figure 6. Radial profiles of Mach number

Using Hutchinson's model [5], the Mach number of the axial plasma flow was deduced from the upstream and downstream ion saturation current radio: $M=0.4\ln(I_u/I_d)$. Subsonic flows (M<0.5) are found. A typical radial profile of parallel flow is shown in figure 6. PDFs of parallel flows are close to gaussian along the plasma column.

4. Summary

Fluctuations of parallel flows, electron density and plasma potencial radial profiles have been investigated in the SLPM-upgrade. First results in SLPM-up are quite similar to those obtained in the former device. A non-gaussian character is also found in fluctuation-induced particle flux statistics. Preliminary results show non-similarity of PDF(Γ_{ExB}). From Mach number measurements subsonic flows (M<0.5) are found. The PDFs(M) are close to gaussian distribution. Dynamical coupling between radial transport and parallel flows is found. Similarities between PDFs measured in this machine with those of fusion plasmas, suggest that the transition from closed to open magnetic field lines is not an important element in order to interpret the structure of turbulence.

Acknowledgments

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