Statistical Properties of Fluctuations in a Linear Plasma Machine: Comparative Studies with Fusion Plasmas

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I. INTRODUCTION

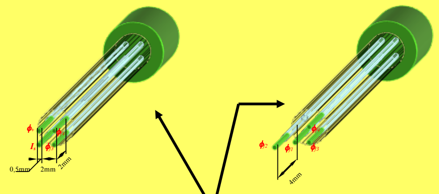
- Although anomalous transport in plasmas has been the subject of many theoretical studies and experimental works, there is not yet a complete understanding of the dynamical mechanisms underlying the transport processes.
- Comparative studies of the plasma turbulence structure in different fusion devices have been carried out [1]. These comparisons support the view that plasma turbulence displays universality [2].
- Recent results emphasize the importance of comparative studies between fusion and non fusion devices[1].
- The statistical properties of plasma fluctuations have been investigated along the whole plasma radial column of a Linear Plasma Machine
- Probability distribution functions (PDF) of electron density, potential and fluctuation-induced flux have been determined.
- PDF's of fluctuating magnitudes and its time derivatives are compared with those of Fusion Plasma devices [3].

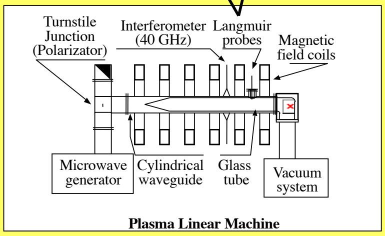
II. EXPERIMENTAL SETUP

Experimental Arrangement

Cylindrical Glass Vessel	Cylindrical Waveguide	RF Source	Magnetic Field	Working Pressure	Working Gas
diameter: 7cm length: 100cm	diameter: 8cm	frec.:2.45GHz power:0.6-6kw regime:continuous	50 mT To 140 mT	10^{-3} mbar to 10^{-1} mbar	Argon Helium Neon

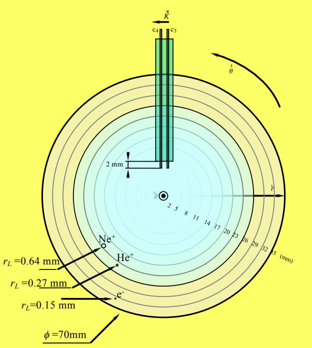
- The plasma is performed in a cylindrical glass vessel located inside a circular waveguide.
- A longitudinally magnetized plasma is produced by launching longitudinally(LMG) electromagnetic waves.
- The system operates in a continuous regime.
- Measurements are performed for Helium and Neon Plasmas.
- Two radially movable array of Langmuir probes provides local values of electron density, floating potential, electron temperature and its fluctuations along the whole plasma radial column





Plasma Linear Machine

III. PLASMA PARAMETERS

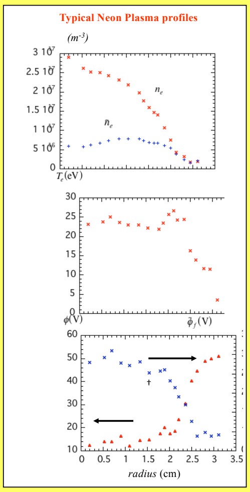


Plasma Cross -Section

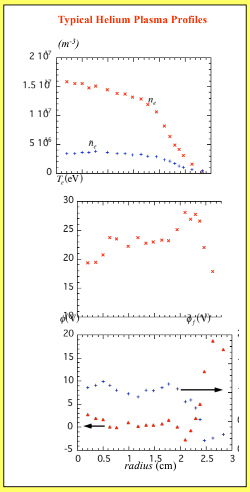
- Electron density and temperature profiles are estimated by means of two poloidally separated probes that were configured in a floating double probe
- Fluctuating magnitudes are determined using a triple probe configuration
- Four Floating Langmuir Probes are positioned along the three directions parallel (u_z), radial (u_r), and poloidal (u_θ) with respect to the magnetic field
- All measurements were undertaken from probe arrays that were moved radially on a shot to shot basis.
- Eight fast data acquisition channels are arranged for fluctuations measurements: 10000 points per channel, sampling frequency 1Mhz with 10-bits resolution.

T_e (eV)	n_e (m^{-3})	λ_D(mm)	ρ_{Le} (cm)	ρ_{Li} (cm)
5-40	5×10^{16}- 5×10^{18}	~3×10^{-2}	~10^{-2}	<1
f_{ce} (GHz)	f_{ci} (kHz)	f_{pe} (GHz)	f_{pi} (MHz)	Ioniz. deg.
2.2 – 3.4	40 – 400	~9	30	<10%

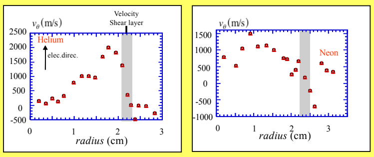
Typical Neon Plasma profiles



Typical Helium Plasma Profiles

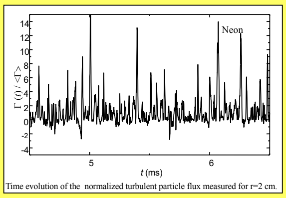


IV. EXPERIMENTAL RESULTS



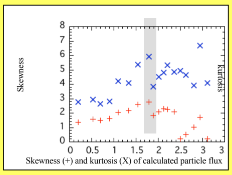
- The study of turbulence is based on the two correlation point technique[4]
- Phase velocity of fluctuations are typically around 2×10^3 m/s
- The velocity shear layer position is located several ion gyroradius from the external surface of the plasma column

$$v_\theta = \frac{\sum_{\omega,k} (\omega/k) S(\omega,k)}{\sum_{\omega,k} S(\omega,k)}$$



Time evolution of the normalized turbulent particle flux measured for r=2 cm.

- The time-resolved radial turbulent flux, $\Gamma = \frac{n E_\theta}{B_z}$ has been measured.
- Fluctuation-induced fluxes have a bursty character
- Statistical properties of the turbulent flux have been determined.
- Skewness goes to S=0 (Gaussian condition) around the shear layer position
- Kurtosis is well above the expected value for a Gaussian distribution (K=3)



Skewness (+) and kurtosis (X) of calculated particle flux

Mean value

$$\mu(x) = \frac{1}{N}\sum_{i=1}^{N} x(i)$$

Standard deviation

$$\sigma(x) = \left(\frac{1}{N}\sum_{i=1}^{N}[x(i)-\mu(x)]^2\right)^{1/2}$$

Skewness

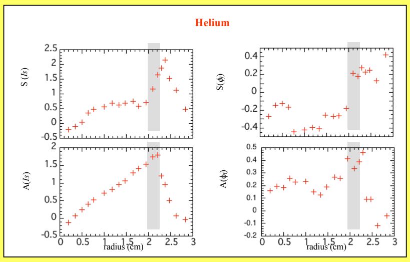
$$S = \frac{1}{\sigma^3(x)N}\sum_{i=1}^{N}[x(i)-\mu(x)]^3$$

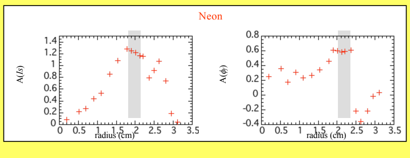
Skewness of the time derivative(Asymmetry)

$$A = \frac{1}{\sigma^3(x')N}\sum_{i=1}^{N-1}[x'(i)-\mu(x)]^3$$

Kurtosis

$$K = \frac{1}{\sigma^4(x)N}\sum_{i=1}^{N}[x(i)-\mu(x)]^4$$





- The skewness of the ion saturation current, floating potential, and their corresponding time derivatives (asymmetry) has been computed using the former definitions.
- The skewness of floating potential deviates from a Gaussian distribution except for the shear layer position.
- The skewness of the ion saturation current is >0 along the radial column.
- The skewness of the derivative show the degree of time asymmetry in turbulent bursts[3]. For A>0 we have fluctuation pulses with a rise time shorter than their decay time.
- Along the plasma column the A value is positive.
- A clear radial change can be observed around the shear layer position on $S(I_s)$, $S(\phi_f)$, $A(I_s)$ and $A(\phi_f)$.
- No significant differences between Helium and Neon plasmas have been found.

V. SUMMARY

- Fluctuations have a non-Gaussian character, mainly out of the velocity shear layer position.
- The radial dependence of $S(\phi_f)$ *and* $A(\phi_f)$ is very similar to that measured in fusion plasmas [3]
- $S(I_s)$ and $A(I_s)$ are always positive values. Unlike it happens on fusion plasmas, both parameters are not cero close to the shear layer.
- For positive defined signals a non-Gaussian PDF is expected (if $\sigma\approx\mu$). However, the changes observed close to the shear layer suggest that this is not the key to explain the lack of Gaussianity measured in fluctuations.
- Fluctuations signals show a bursty character, with spikes nonsymmetric in time as shown by the skewness of the time derivative.
- In the present experiments the value around the shear layer of the decorrelation shearing rate is about $B^{-1}dE_r/dr\approx10^4$ s^{-1} which is comparable of 1/τ with τ=auto-correlation time of fluctuations. This behaviour could be related with the time asymmetry observed in the bursts.
- The striking similarity between the 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.
- Experimental results emphasize the important role that nonfusion devices could play to clarify some aspects of plasma turbulence.

References

[1] J. W. Connor et al. Plasma Phys. Control Fusion 41, 693 (1999)

[2] M. A. Pedrosa et al.Phys. Rev. Lett. 82, 3621 (1999)

[3] E. Sánchez et al. Phys. Plasmas 7, 1408 (2000)

[4] S. J. Levinson et al. Nucl. Fusion 24, 527 (1984)

[5] B.A. Carreras et al. Phys. Plasmas 3, 2664 (1996)