Comparison of Tokamak Plasma Midplane with Divertor Conditions

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Abstract

In this paper, we present results of profile of ion saturation current and its fluctuation statistics obtained from Langmuir probe measurements in the X-point region of ASDEX Upgrade. The machine was operated in L-mode and heated with electron cyclotron resonance heating(ECRH). Analysis of the time series show a significant difference between the probability distribution function and power spectral density, obtained at the low field side and high field side of the X-point.

Introduction

Turbulence causes particle, energy and momentum transport in the edge and into the scrape-off layer (SOL) of magnetically confined plasma, thus having a key role in the plasma edge of tokamak devices. The turbulent transport associated with filamentary structures known as 'plasma blobs' determines the confinement of the plasma and lifetime of plasma facing components (PFC)[1]. To be able to predict the erosion and damage of the PFCs, especially relevant for ITER, measurements of fluctuating and time averaged quantities of the SOL turbulence are required. Statistics of impinging plasma fluxes in the SOL are therefore of great interest [2, 3]. To gain an insight in the dynamics of the SOL, it is vital to consider both the low field side (LFS) SOL and the high field side (HFS) SOL. However, the understanding of the SOL physics is so far underdeveloped by the relative scarcity of systematic measurements in the region around the X-point and mostly due to the extreme poloidal and toroidal localization of these measurements. The X-point manipulator (XPM) at ASDEX Upgrade increases the poloidal diagnostics coverage [4, 5]. This enables measurements in both the LFS and HFS SOL, allowing for a comparison between the plasma profiles in the HFS and LFS, as well as in the private flux region (PFR). The presented measurements in this paper, are obtained approximately 1 cm below the X-point.

Experimental setup

The main focus of this contribution is the study of statistical properties of the fluctuation obtained in the X-point region at ASDEX Upgrade by means of a fast reciprocating probe system. The poloidal cross-section of ASDEX Upgrade is shown in figure 1. The XPM and its trace, represented by the black line in figure 1, are located at $z = -0.996$ m. The magnetic flux reconstruction for #36347 (at $t = 5.1$ s) is shown in red. The blue line shows the separatrix. For the typical equilibrium, the XPM falls below the X-point. The probe head consists of three cylindrical graphite tips, two of which are in Mach probe configuration and oriented in such a way as to measure the toroidal flow component of the ion saturation current (I_{sat}), upstream and downstream. The I_{sat} measurements are performed at -200 V. The last pin is separated and is swept at a frequency of 1 kHz between $\pm$ 150 V. The data discussed in this contribution is for a lower single null L-Mode plasma (#36347) obtained in May 2019. The parameters for this discharge are: plasma current of $I_p = 0.8$ MA, a toroidal field of $B_t = -2.4$ T, line integrated density of $\bar{n}_e = 5.9 \times 10^{19}$ m^{-3} and a total heating power of 0.7 MW through ECRH. In the first plunge the XPM is moved to a radial position of $R = 1.50$ m (LFS SOL) and a stationary measurement was taken for 50 ms. In the third plunge the XPM was driven to the maximum position $R = 1.35$ m (HFS SOL) and the stationary measurement was taken for 50 ms.

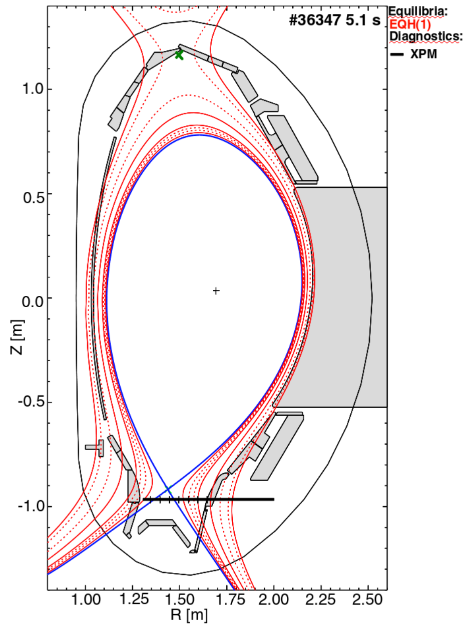
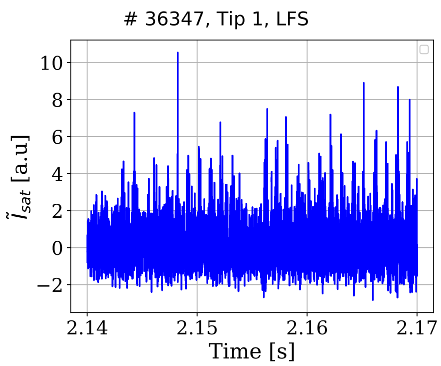
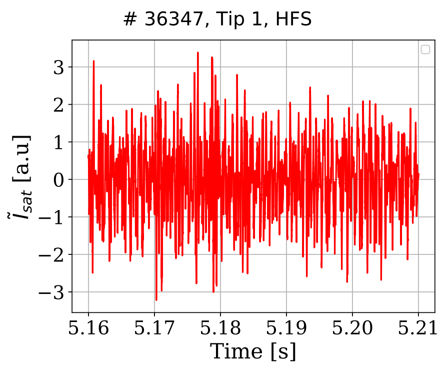


Figure 1: *Experimental setup of XPM and plasma configuration of the 3rd plunge with secondary X-point in green, XPM trace is in black.*

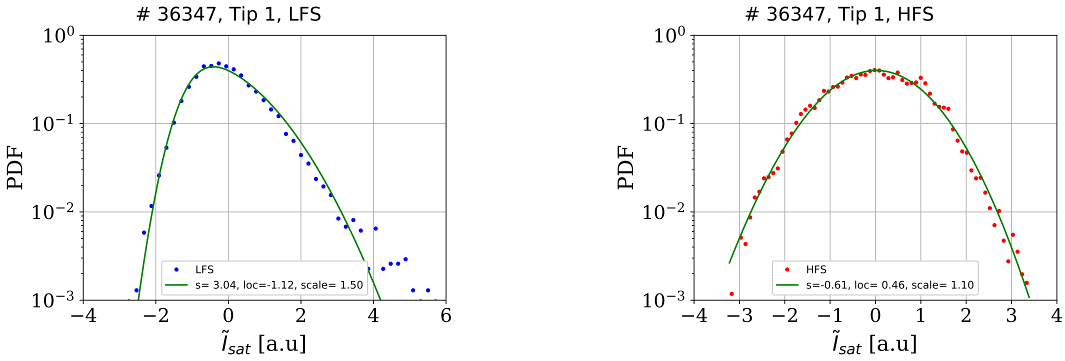


(a) LFS, plunge 1



(b) HFS, plunge 3

Figure 2: *The normalized and filtered I_{sat} data.*



(a) LFS, plunge 1

(b) HFS, plunge 3

Figure 3: *Probability distribution function of* $\tilde{I}_{sat}$.

Results

Table 1: *Comparison of the moments of both plunges.*

Plunge	Skewness	Flatness
LFS	1.32	8.06
HFS	-0.05	2.72

The data analysis is conducted on time trace of the ion saturation current,I_{sat}, measured. With $\sigma_{I_{sat}}$ being the standard deviation and $< I_{sat} >_m$ the mean value, the turbulence strength $\sigma_{I_{sat}} / < I_{sat} >_m$ of the raw data are 0.192 and 0.178 for the LFS and HFS respectively. The turbulence strength of the LFS and HFS are similar, meaning that the HFS measurement is above the noise floor. This can be interpreted as local generation of turbulence on the HFS region [10]. For the analysis, the data time series, I_{sat}, were normalized as follows [3]: $\tilde{I}_{sat} = \frac{I_{sat} - <I_{sat}>_m}{\sigma_{I_{sat}}}$, . Figure 2a and 2b show the normalized data $\tilde{I}_{sat}$. A high pass filter at 1 kHz was applied to the data to suppress cross-talk between the pins. The signal from the HFS has a more symmetric characteristic (amplitude is between ± 2) compared to the LFS (amplitude is between -2 and +10). The symmetry in the signal of the HFS indicates a Gaussian distribution. Table 1 shows the moments calculated for the filtered normalized signals. It is observed that the skewness and flatness of the LFS plunge are greater than those of the HFS plunge. Figure 3a and 3b show the probability distribution function (PDF) associated with the data from the LFS and HFS. It is observed that the PDF of the LFS is more skewed compare to the HFS. The PDF obtained in the HFS is slightly negatively skewed whereas the PDF of the LFS is positively skewed. Both PDFs have been fitted by a skew normal distribution. The fitting parameters obtained are skewness s, position of the maximum loc, and the amplitude of the fit, scale, respectively. The positive skewness in the LFS SOL indicates the presence of blobs propagating in the SOL[6]. Discrepancy in the fitted skewness to the calculated one of the LFS data (figure 3a and table 1) is because the fit cannot describe the tail properly. Since the secondary X-point (green cross in figure 1) is within the vacuum vessel, it might be possible that the filaments coming from the outboard midplane propagating towards the inner target (HFS) are dispersed due to shearing by the two X-points causing no blob detection during the plunge. This can therefore explain the observed Gaussian profile. The minor negative skewness of the HFS indicates that holes formed due to interchange modes are propagating outward (towards the HFS wall) [7, 8]. Figure 4 shows the power spectral density (PSD) of both plunges. The PSD of the HFS decays more rapidly compared to the LFS plunge. On fitting a straight line to the log-log plot of the two PSD, spectral indices of -0.5 and -3.7 are obtained for the LFS and HFS data, respectively.

Summary

The results (PDFs) show that the fluctuations in the LFS are larger and more intermittent compared to those in the HFS [9]. A Gaussian profile may be expected in the HFS due to the ballooning effect. However, it is observed that the level of fluctuation is similar to the LFS, indicating that the measurement is larger than the noise floor. This can be interpreted as some local generation of turbulence in the HFS region. The power spectral density indicates that the HFS turbulence is dominated by low frequencies. This might indicate a weak drive to the turbulence [10]. Correlating the results with those at the midplane and PFR will hopefully give the required insight to have a better understanding of the SOL physics.

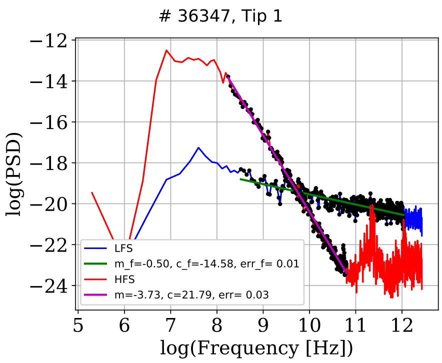


Figure 4: *Power spectral density obtained for the LFS and HFS plunge.*

Acknowledgement

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