Time correlated bursts in Texas Helimak

ID: 105

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ABSTRACT

- This work study evidences of time-correlation between bursts that were observed in TEXAS Helimak (PEREIRA, 2019). The aim is to check the reproducibility of the results reported in this article, extending the analysis to plasma discharges with similar conditions as well as in different regimes.
- It was discovered that using different gas, He and Ar, the regime of time correlated bursts appears in different radial regions.

BACKGROUND

The analysis was conducted using ion saturation current acquired from Langmuir probes placed on plates inside the Texas Helimak with positive bias applied to one of the plates. The classical Stochastic Pulse Train Model (SPTM) assumes that the timing of bursts in a confinement plasma machine is random, therefore, the time interval between successive bursts should follow an exponential distribution (GARCIA, 2012). However, it is not the case when a positive bias is applied to a certain region in the Texas Helimak, it appears that there is some time correlation between bursts, which increases for positive bias. These phenomena can be observed through the presence of peaks in the base of conditional average of burst, Power Spectrum Density and time interval histogram, as seen in the figures 1 and 2.

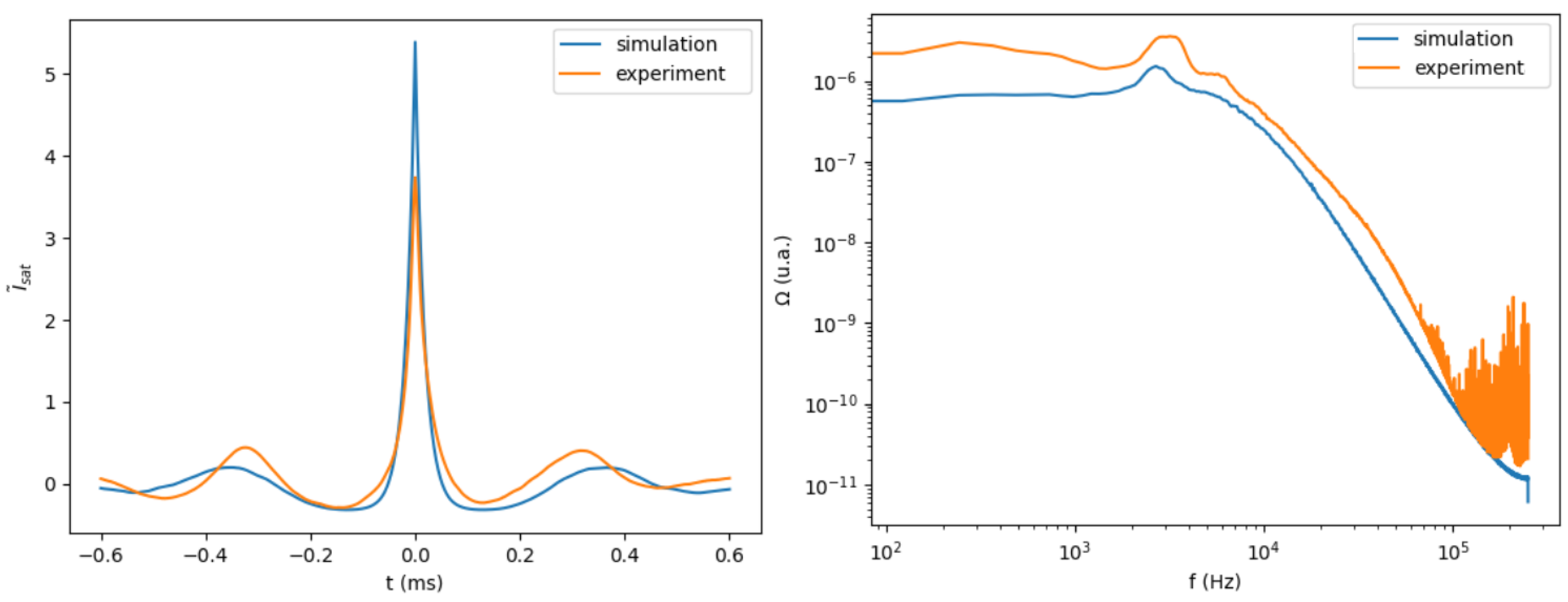

Figure 1 – Comparison of simulation with experimental result using gas Ar; left: Conditional average of Bursts; right: Power Spectrum Density.

CHALLENGES / METHODS / IMPLEMENTATION

The reference article suggests that the time interval between successive bursts follows a gamma distribution, but since not all bursts are detected, an equation in Fourier domain was developed in that paper, considering the probability of burst detection, α, with threshold of 2 standard deviation above the mean:

$$P(\omega) = \frac{\alpha}{(1 + i\omega s)^k - (1 - \alpha)},$$

where k and s are shape and scale parameters of gamma distribution. When k>>1, it indicates a strong correlation in time between bursts, whereas k=1 returns an exponential distribution, implying no correlation.

The fit was performed using the Inverse Fast Fourier transform of P(ω) with 2^{14} interpolated points for both gases. A nonlinear least-squared method was used for He, while for Ar, the fit was done by iteratively adjusting the parameters to minimize the chi-square in the peak region of the time interval histogram.

For Ar, the first points of the time interval histogram are much higher than the fit function P(ω). This can be reproduced via simulation, considering two pulses regimes: one where the time interval follows a gamma distribution and another where the pulse background appear randomly.

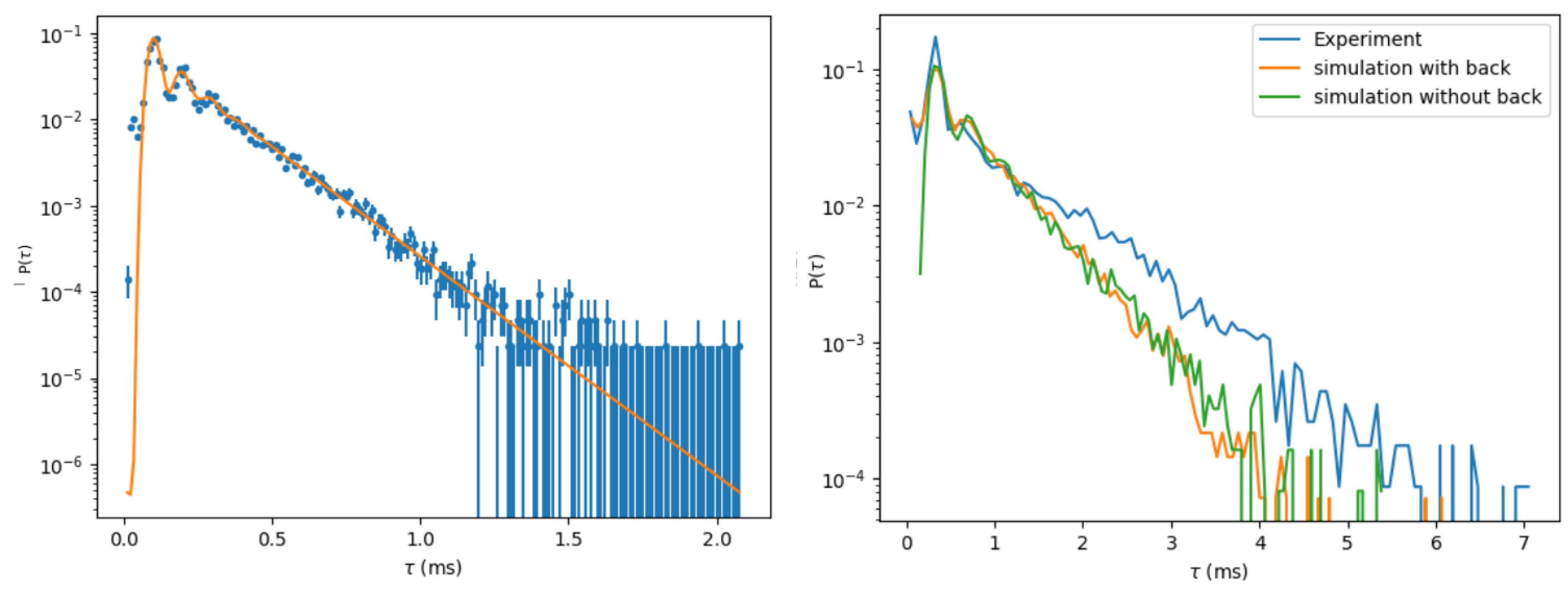

Figure 2 – Histograms of time interval between bursts; left: Fit with gas He; right: Comparison of experimental Ar data with simulations with and without a portion of random background bursts.

OUTCOME

The time correlation between bursts depends on radial position and positive bias, as indicated by parameter k in figure 3. Moreover, the emergence of correlation is related to type of gas used. For He, the parameter increases in the inner region of Helimak, whereas for Ar, it increases in the outer region. Figure 4 shows histograms viewed from the "top", with the red line corresponding to the first peak in the histogram from figure 2, demonstrating that parameter k is a good indicator for identifying time correlated bursts regimes.

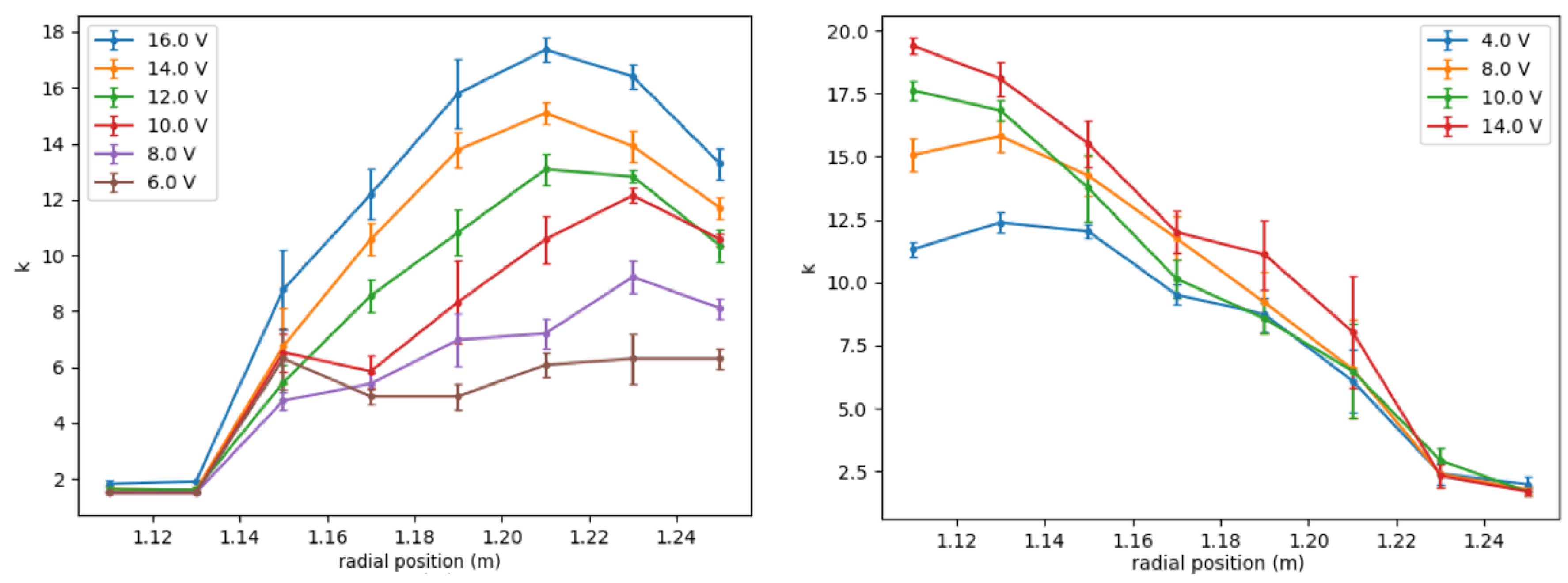

Figure 3 – Radial profile of average parameter k for different values of bias at different heights; left: gas Ar; right: gas He.

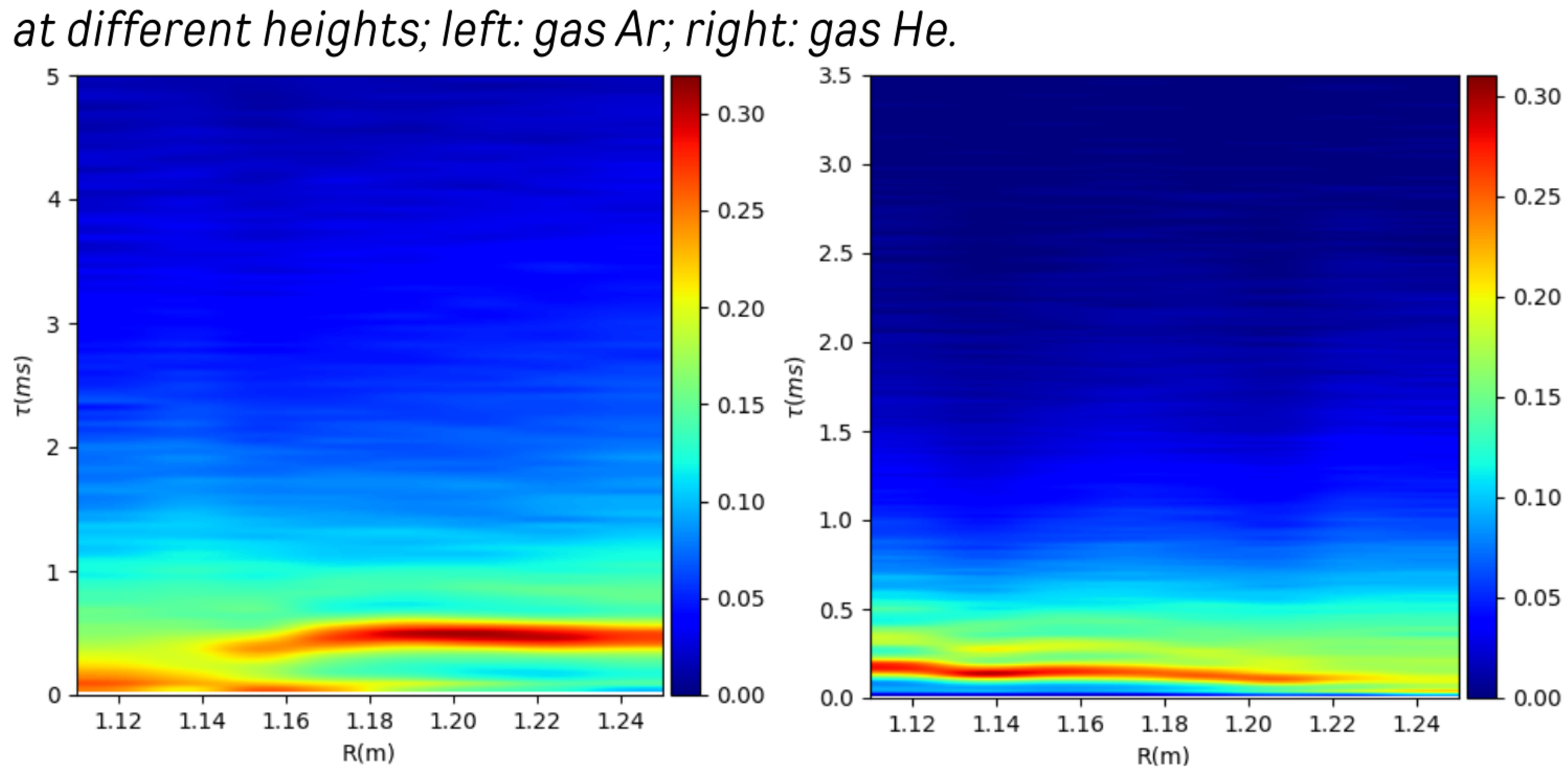

Figure 4 – 3D Histograms of time interval at height 0.233 m with bias 14V; left: gas Ar; right: gas He

CONCLUSION

Although the expression for the pdf of time between successive detected bursts, P(ω), is incomplete, it is still able to identify time correlated bursts regimes by estimating the parameter k. Therefore, it would be interesting to improve the function P(ω) by considering the second pulse regime, as it currently only takes account for the time correlated regime. Further work could investigate the reasons behind the periodicity of burst occurrence under these specific conditions.

REFERENCES

- PEREIRA, F. A. C. et al. *Statistical properties of intermittent bursts in the texas helimak*. Physics of Plasmas **26**, 052301 (2019).
- GARCIA, O.E. *Stochastic Modeling of Intermittent Scrape-Off Layer Plasma Fluctuations*. Physical Review Letters **108**, 265001 (2012).