Plasma Structures in Texas Helimak

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Preâmbulo: IFSP: Inst. Federal de Educação, Ciência e Tecnologia de São Paulo

- O IFSP é uma instituição de ensino tecnológico de nível médio e superior:
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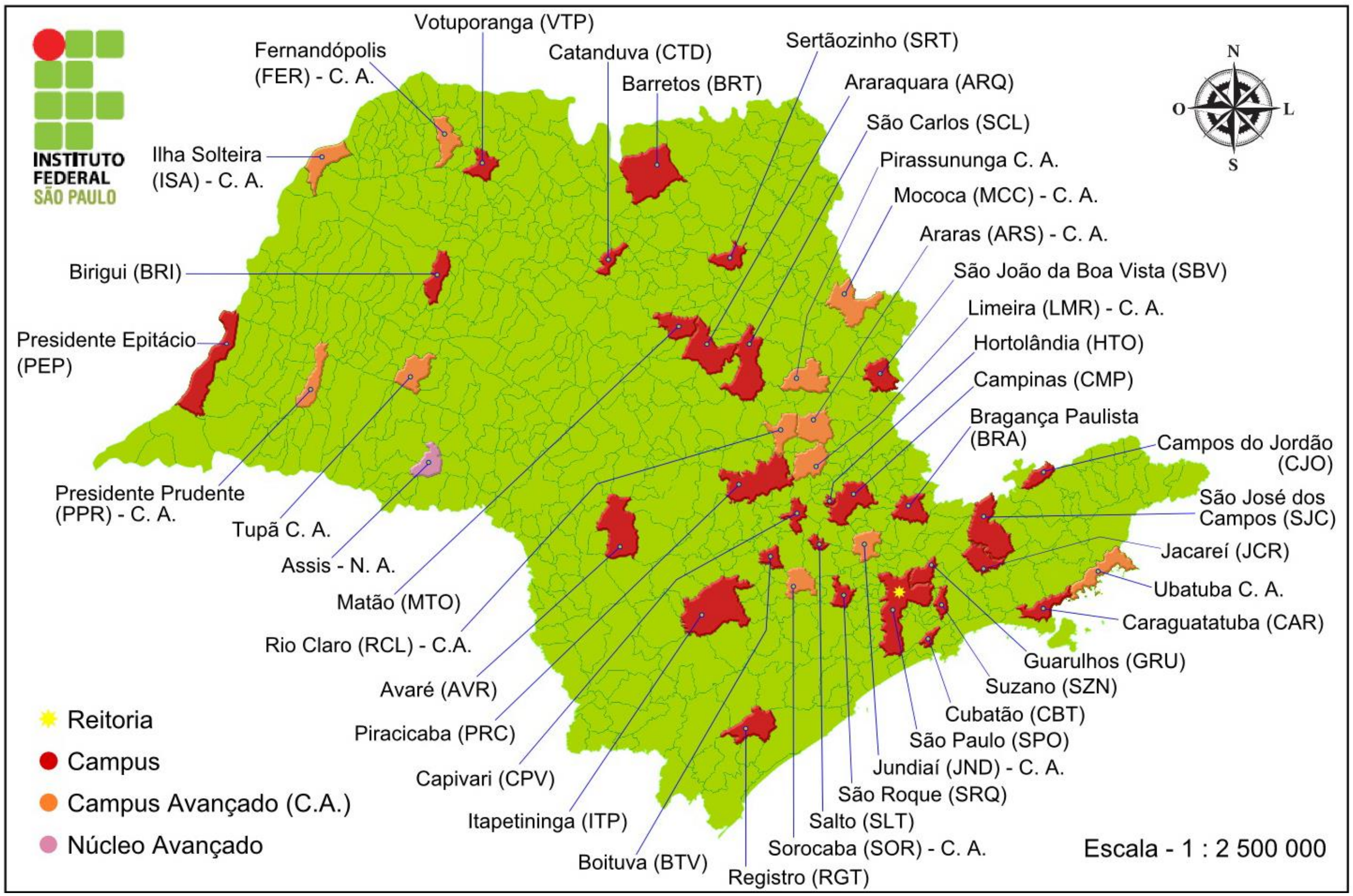


Sumary

1. Introduction;
2. Texas Helimak;
3. Bias induced bursts;
4. Bursts properties;
5. Bidimensional analyses;
6. Conclusions and Perspectives;

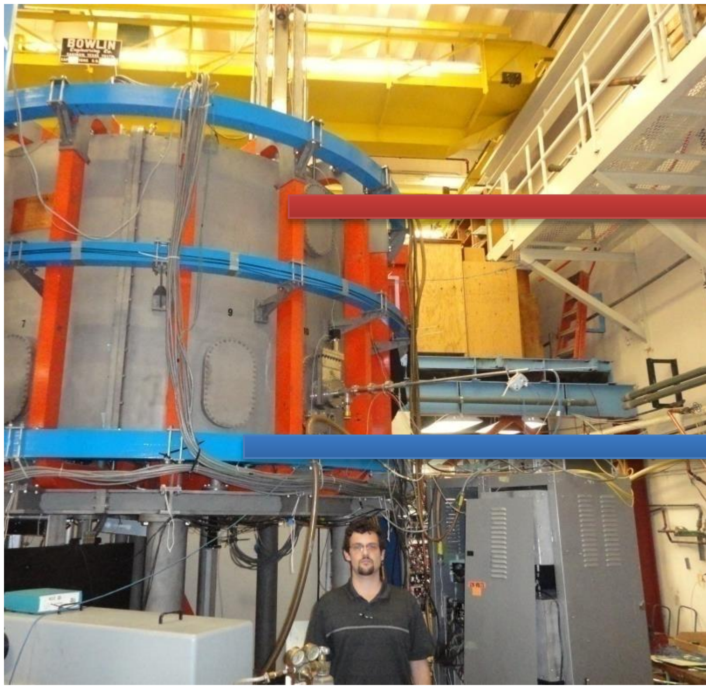
1. Introduction

- Understand the turbulence in the plasma edge is important to plasma confinement.
- Investigate the influence of the radial electric field profile in the turbulence is important once was experimentally observed that changes in this profile can reduce the particle loss in the edge of the plasma.
- Basic confined plasma machines are important tools to investigate the turbulence and its dependence:
  - stable and reproducible discharges;
  - Large array of probes;
  - Examples: Texas Helimak, Torpex, BLAAMANN;

2. Texas Helimak

- Toroidal machine with simplified magnetic field lines configuration = > basically one dimensional equilibrium (dependence on the radial coordinate).
- Helimak works with a “cold” plasma similar to those the edge and the scrappe-of-layer of a medium size tokamak.
- The waves propagation occurs on the vertical (z) direction in a similar way that it occurs in the poloidal direction in a tokamak.

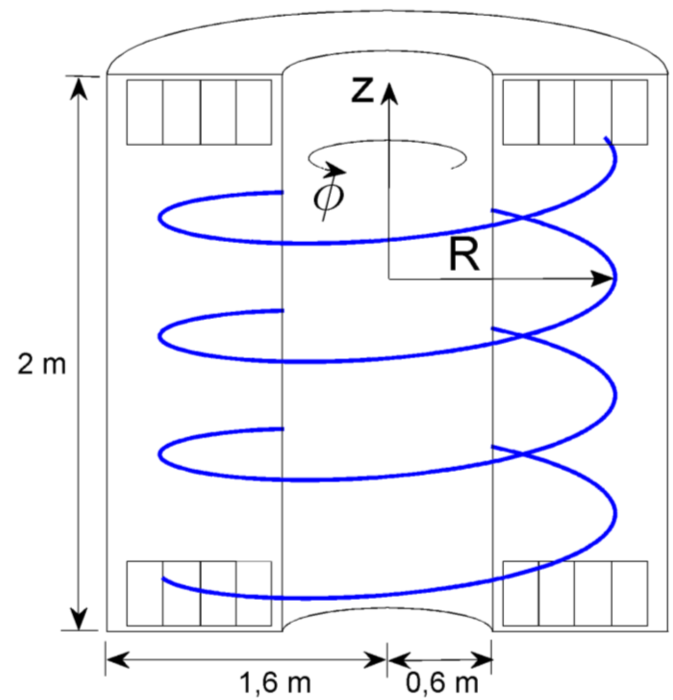
B field lines geometry



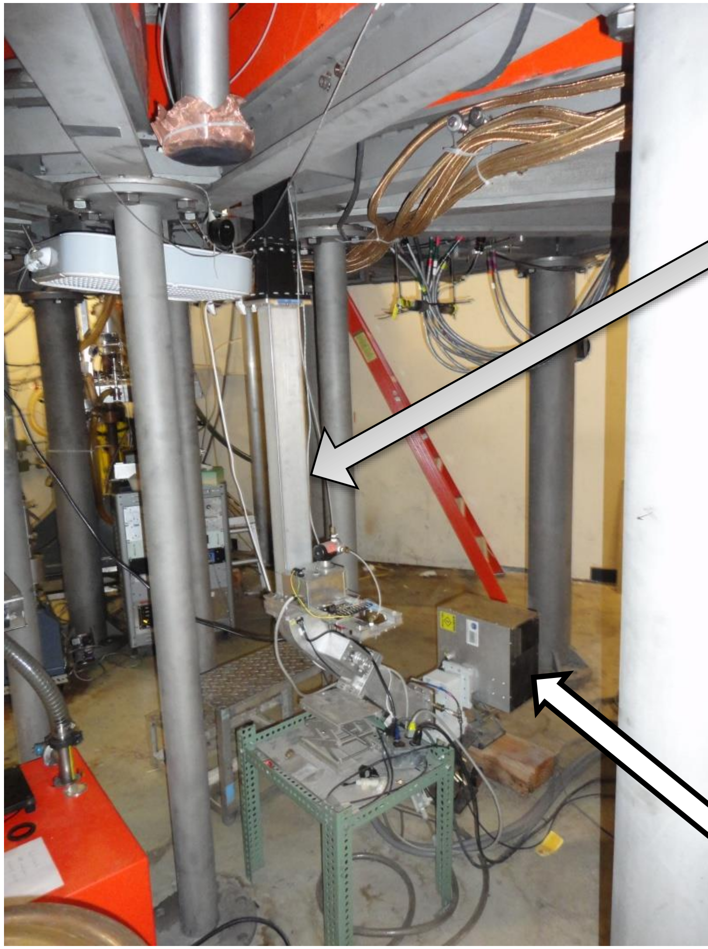
16 toroidal Coils

+

3 vertical coils



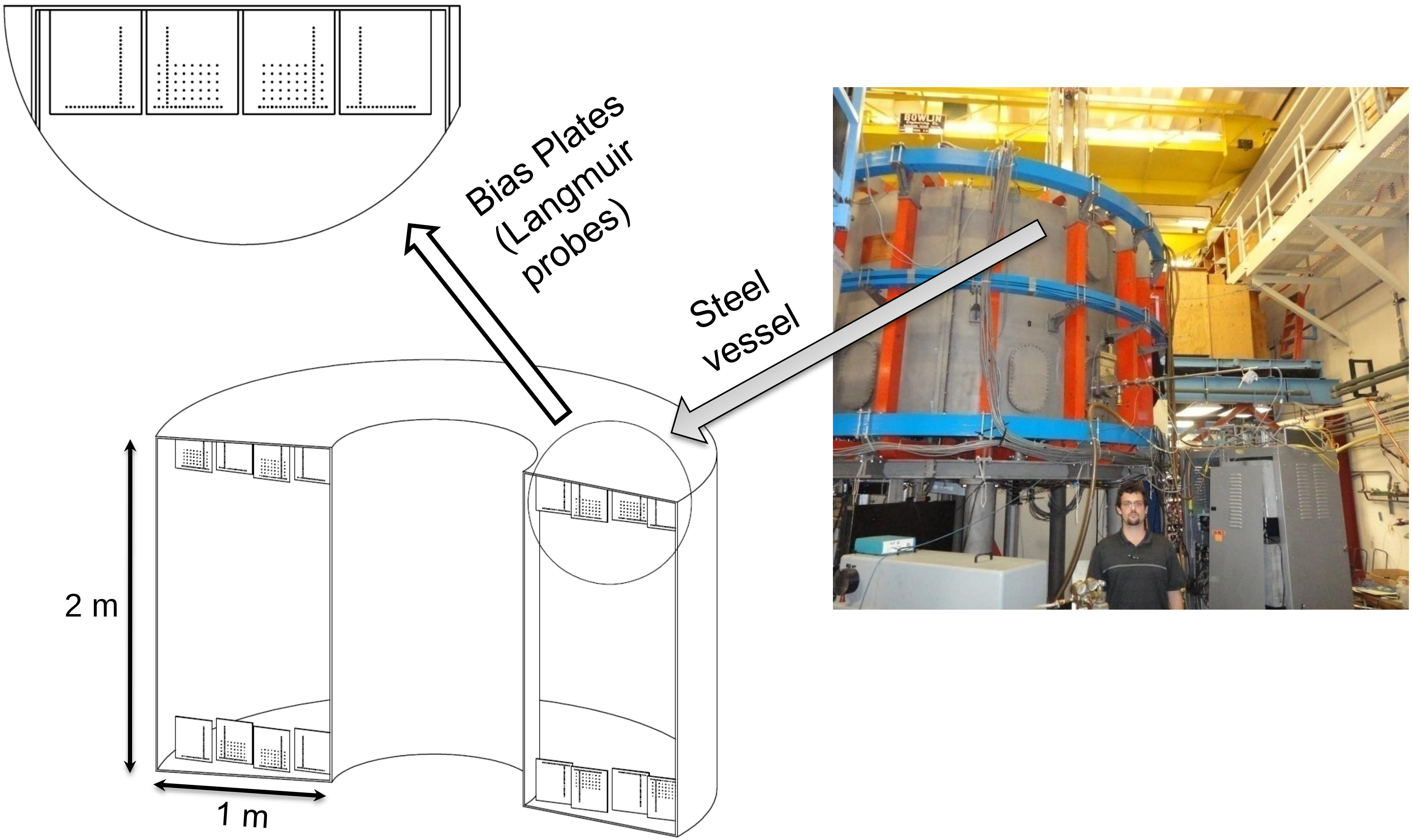
ECRH (Electron cyclotron resonance Heating):



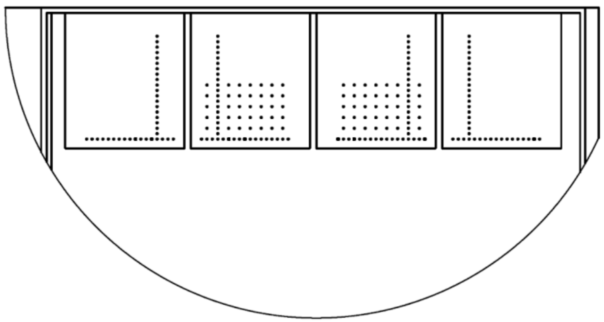
Wave guide

Microwave source

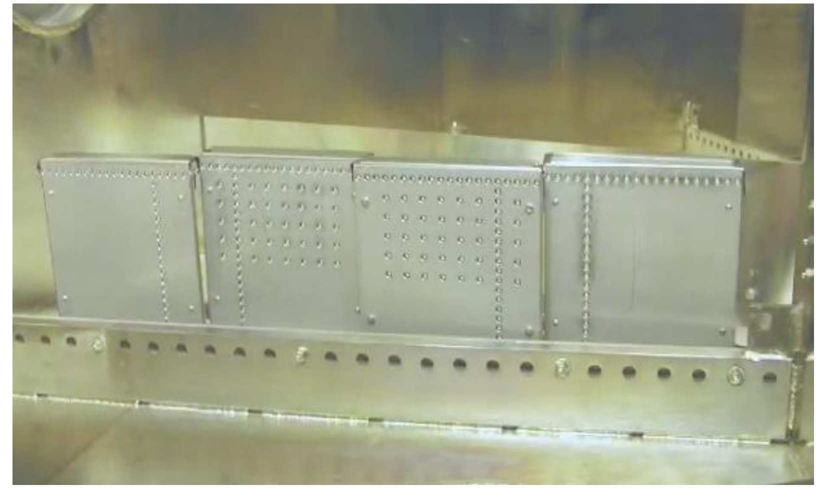
Vessel, bias plates and probes

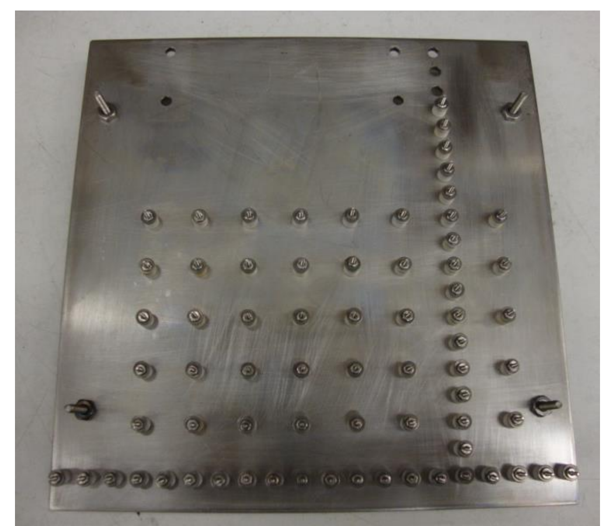


Langmuir probes



Bias plates
(Langmuir
probes)



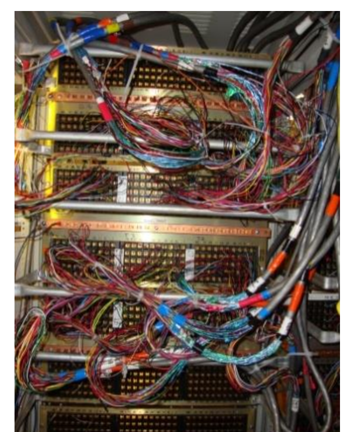


- Approximately 700 Langmuir probes;
- 2 ADCs:
  - Slow: → mean profiles measurements
    - 128 channels and ~7kHz of sample rate;
  - Fast: → turbulence measurements
    - 96 channels e 500 kHz.

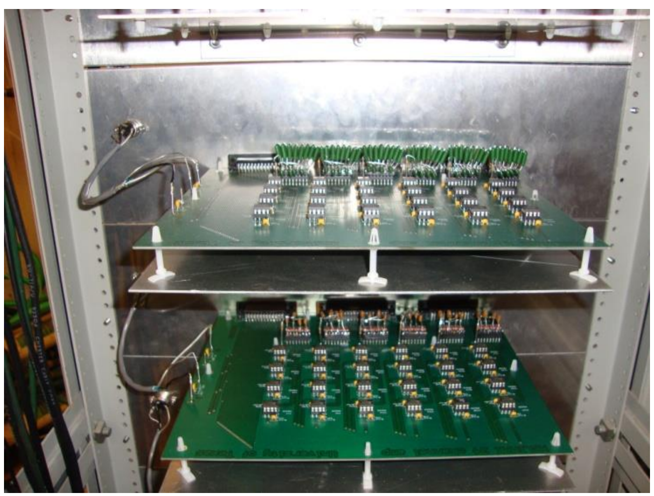
Langmuir probes

Flat cables (Langmuir probes)

Panel of connections

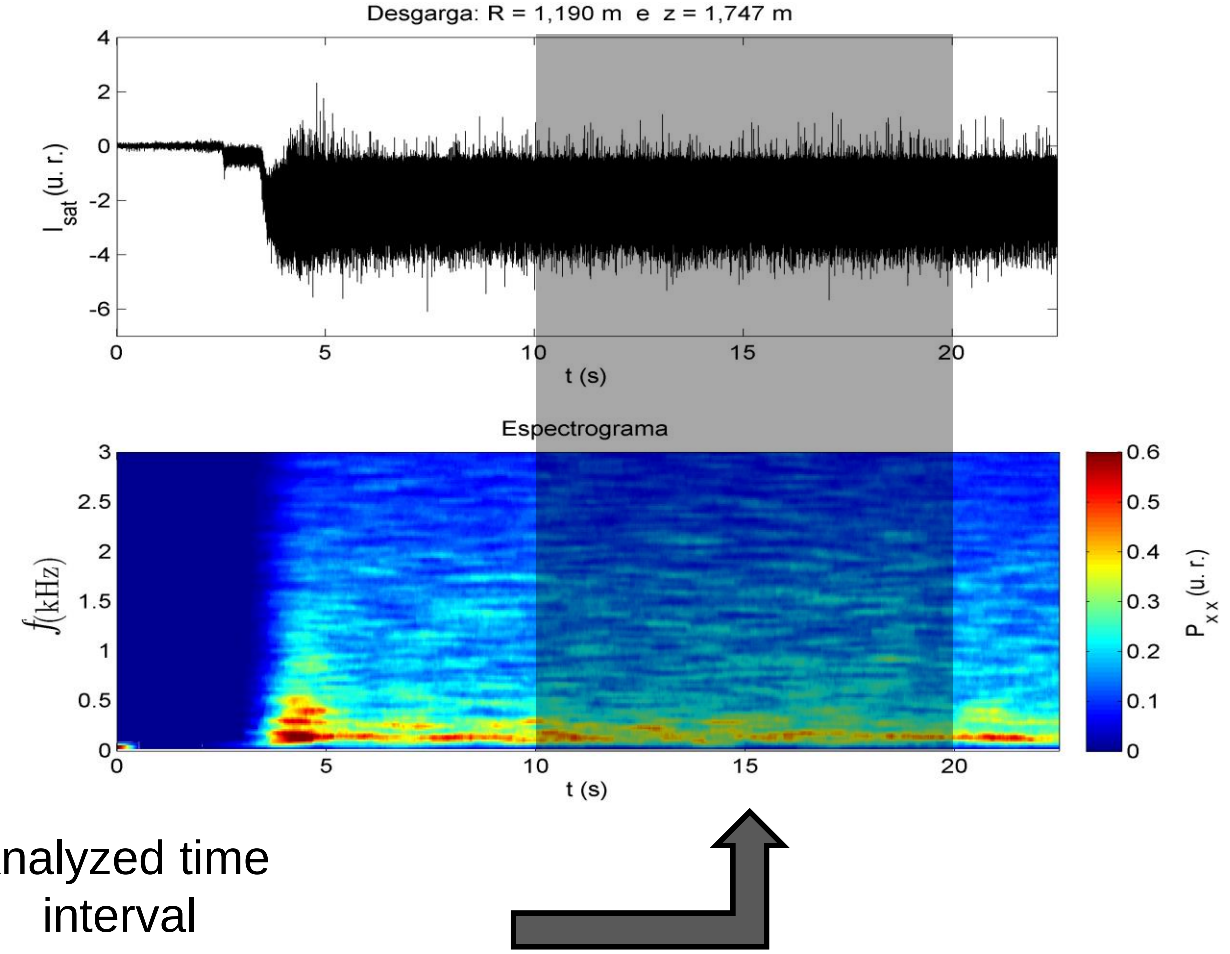


amplifiers



Typical discharge

- Stationary discharges with more and 20 s duration;



Analyzed time interval

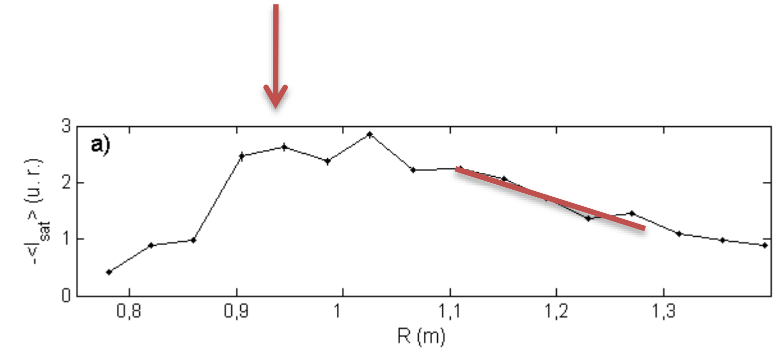
Parameters:

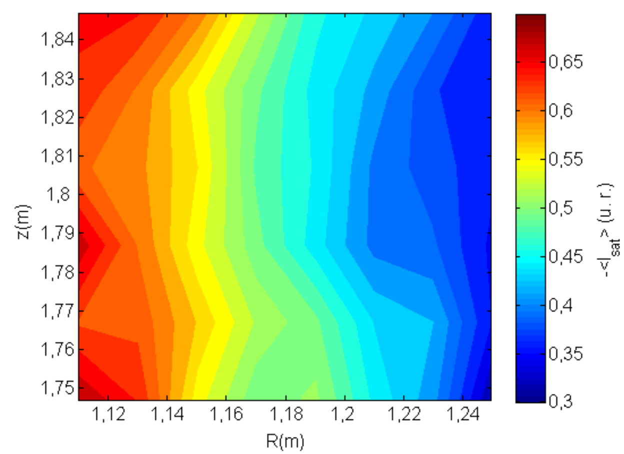
I_{sat}

Maxb I_{sat} for
R = 0,95 m

dI_{sat} / dR aprox. constant
for 1,10m < R < 1,25 m

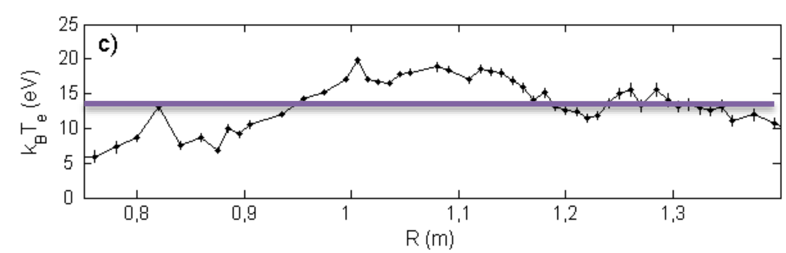
vertical position
Independence





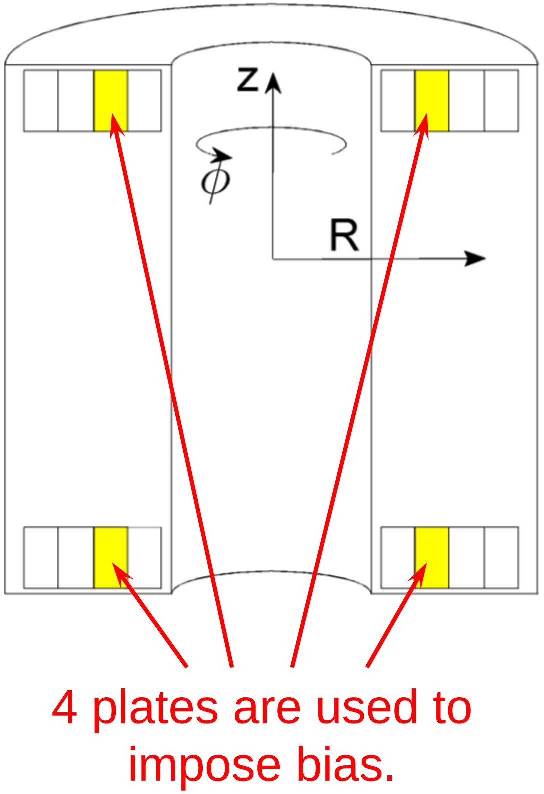
T_e

Mean Te
around 13eV



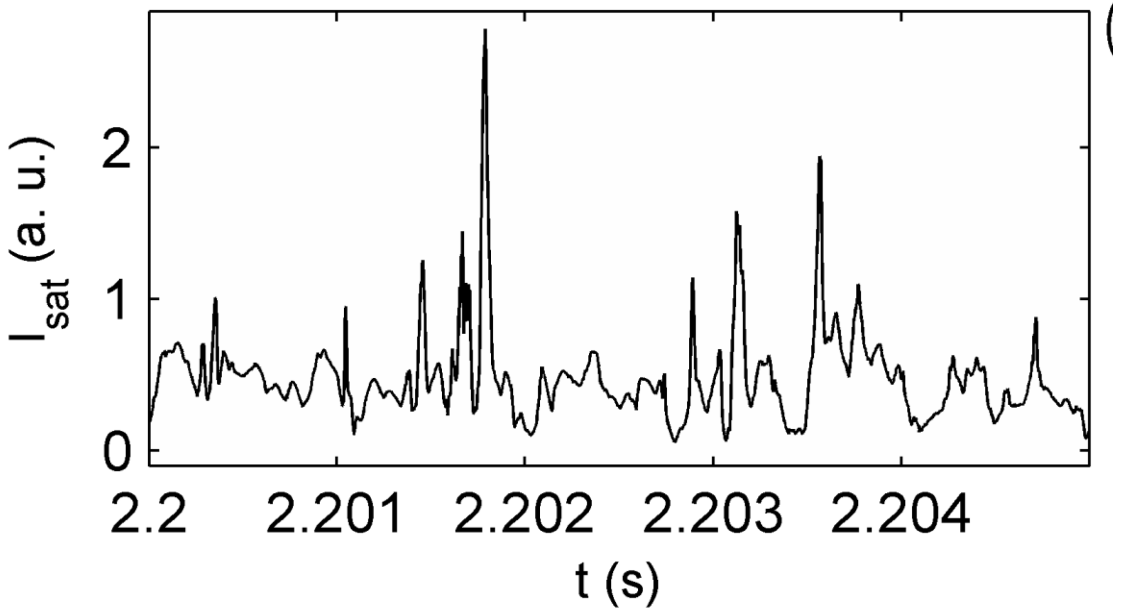
External bias

- External electric potential (bias) applied in 4 of the 16 plates, localized between R = 0,863 m and R = 1,075 m.
- In these presented results the bias value was varied from +2 V to +15 V.
- For these analyzes the radial position was fixed in the region of the expected maximum dE/dR: R= 1.11 m.



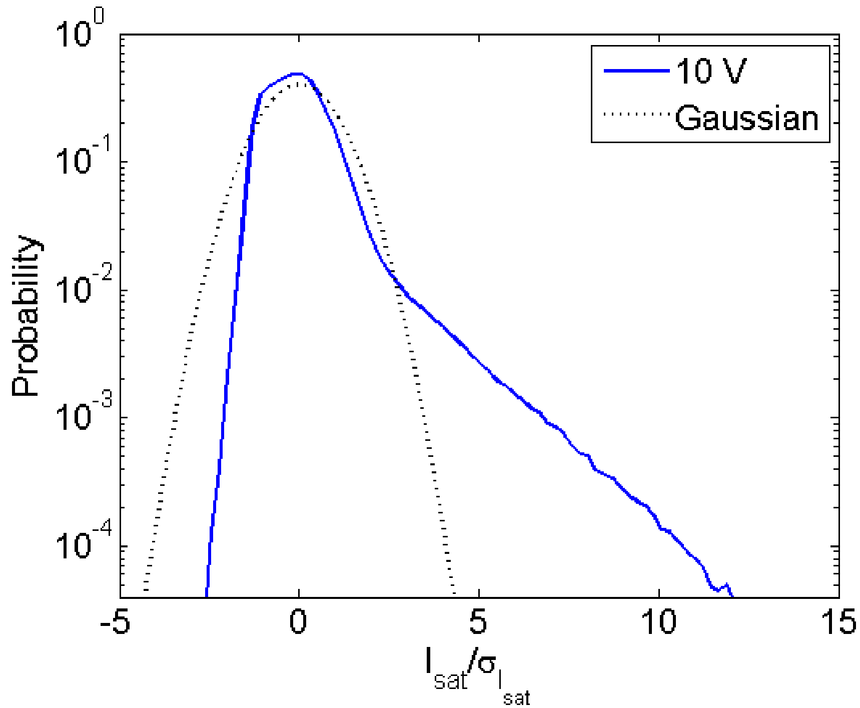
3. Bias induced bursts

For positive imposed bias, the I_{sat} signals presents thin *spikes* (bursts)*:



*TOUFEN, D. L. at. al. Analysis of the Influence of External Biasing on Texas Helimak Turbulence. **Physics of Plasma**. 20, 022310 (2013).

Turbulence dominated by extreme events

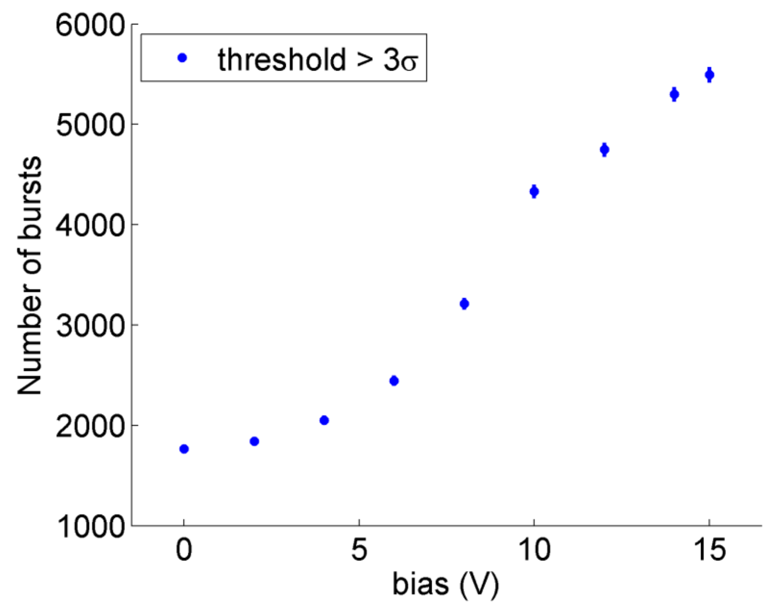


Non Gaussian PDF with a long tail is an indication of intermittent bursts.

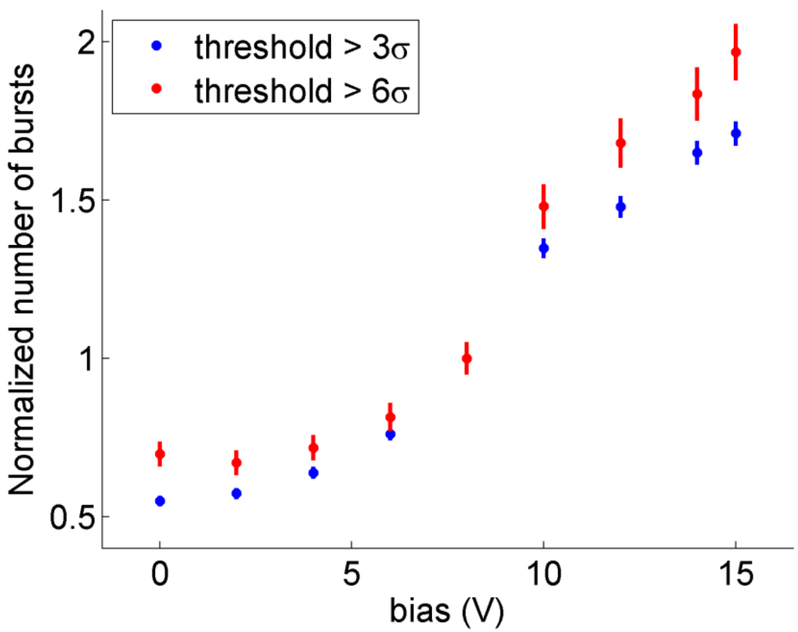
Number of bursts as a function of bias

One burst is defined as a peak with a maximum value higher then the defined threshold.

Number of bursts increases for higher applied bias values.



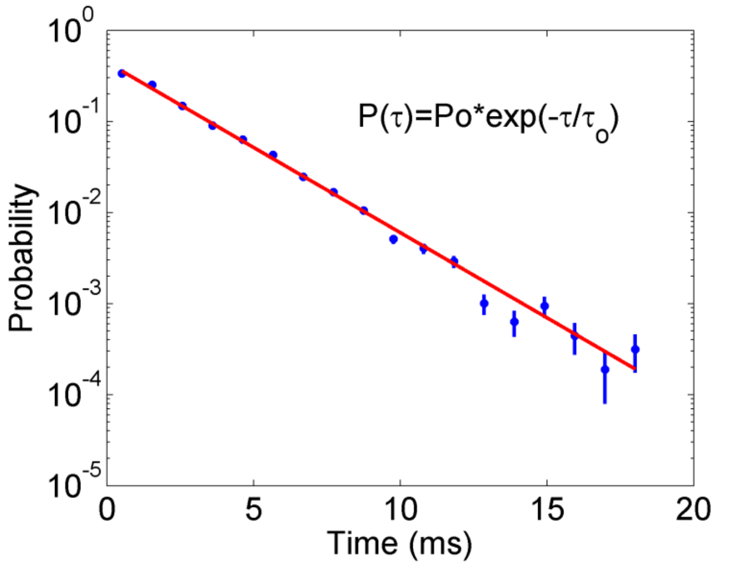
Normalized number of bursts does not depend of the threshold value.



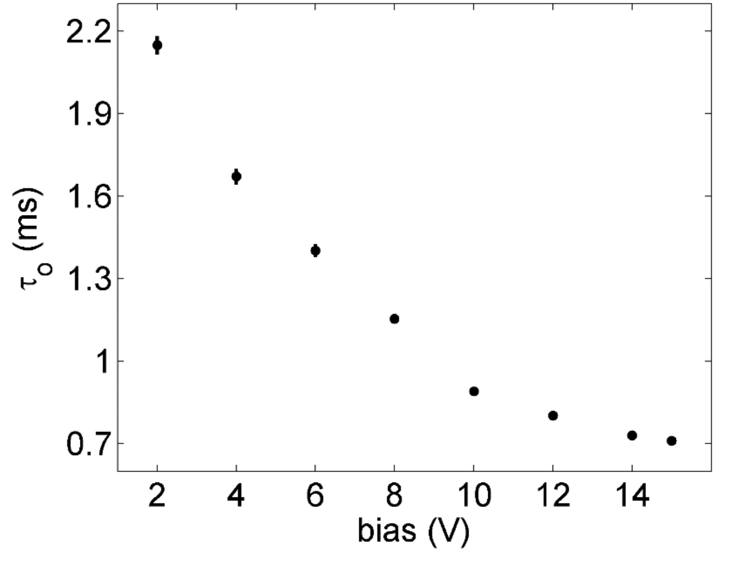
4. Bursts properties as function of the bias value

Probability of time between successive bursts

Probability distribution of time intervals between successive bursts P(τ) shows an exponential distribution => no correlation between one and the next burst.

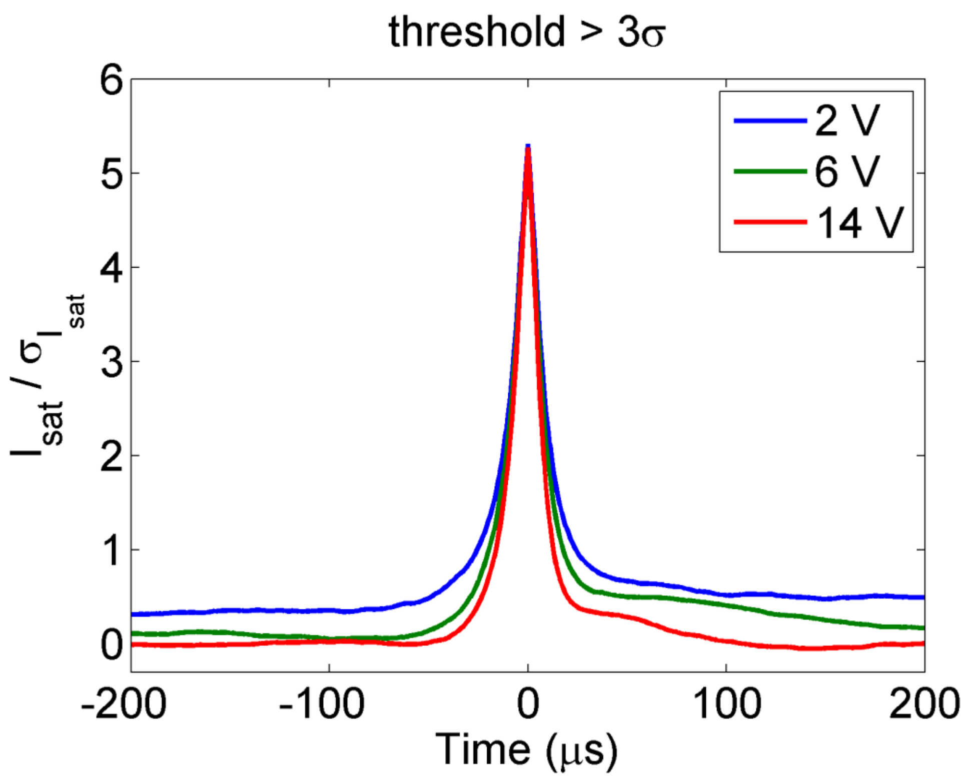


Time characteristic (τ_o) becomes lower for higher bias.



Mean burst width

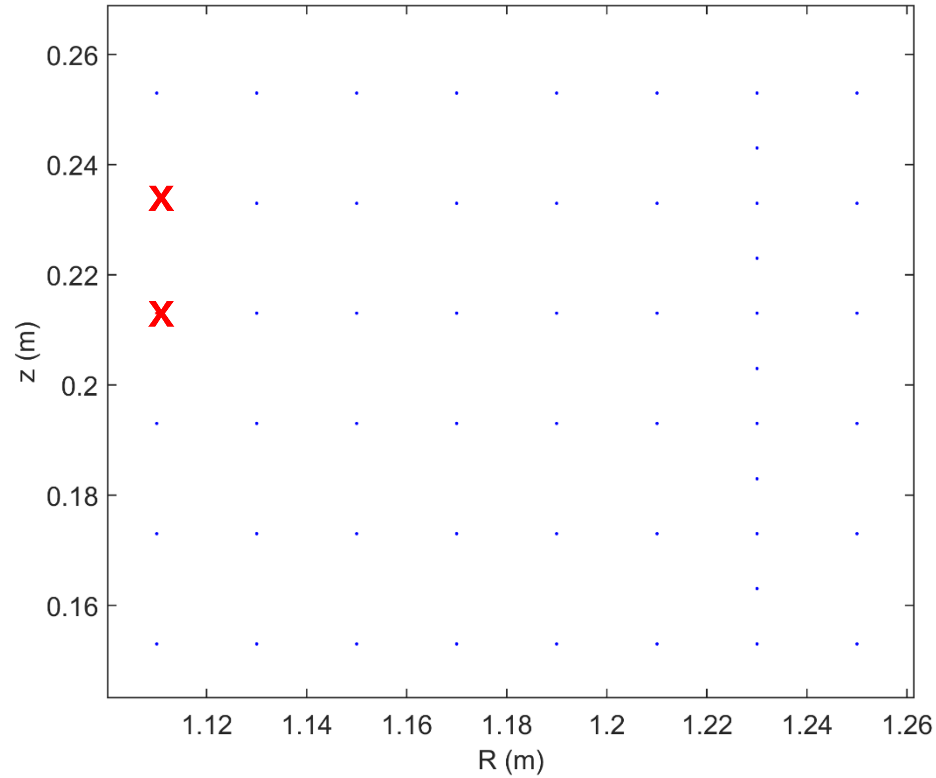
The bias value does not affect the mean pick width, just changing the base line value.



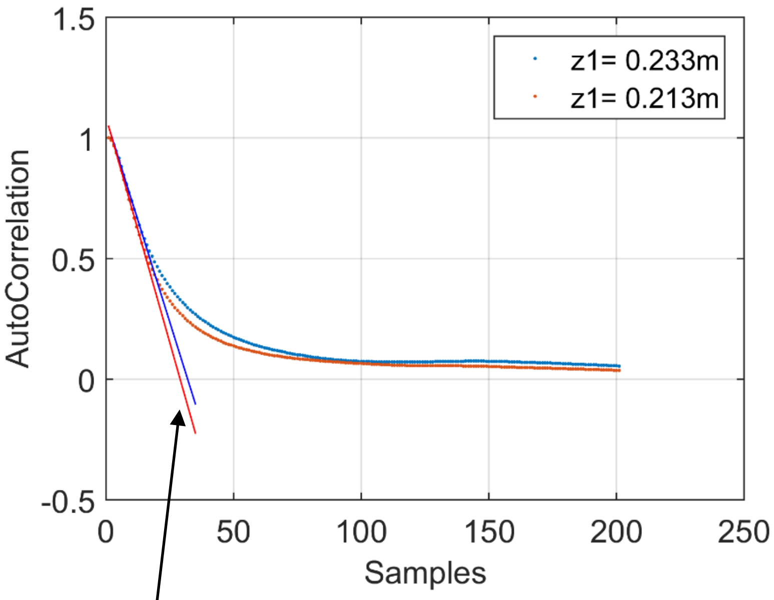
New Topic – bidimensional study

The analyze begins with two I_{sat} series from close probes:

- Two probes at: R=1.11m, Z= 0.233 and 0.213m
- Bias = 14 V.



To define the time step size we calculate de autocorrelation:



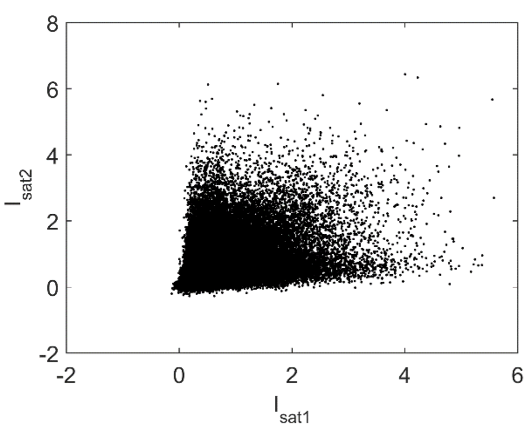
Decorrelation time:

Decorrelation time:

τ_{decor} ~ 30 samples (60µs)

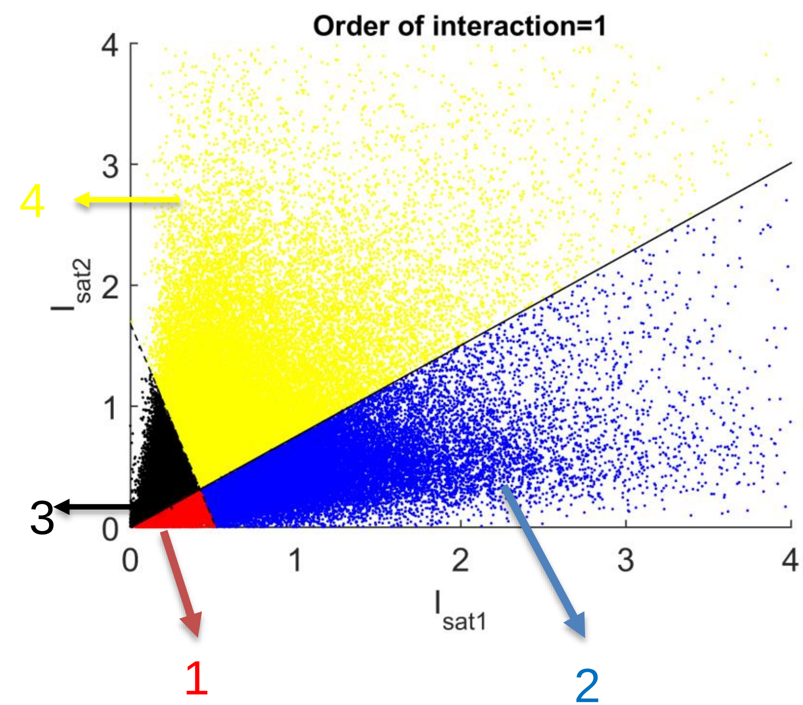
Phase space and partition:

- Phase space will be the simultaneous value for both probes (Delay = 0).
- Then, we define a partition to distribute the points aprox. Equally.



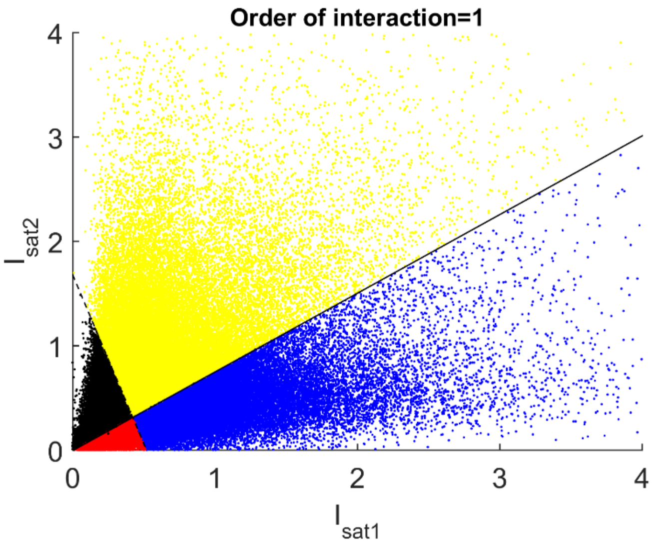
Define a partition

Ns=80918 80916 80921 80918

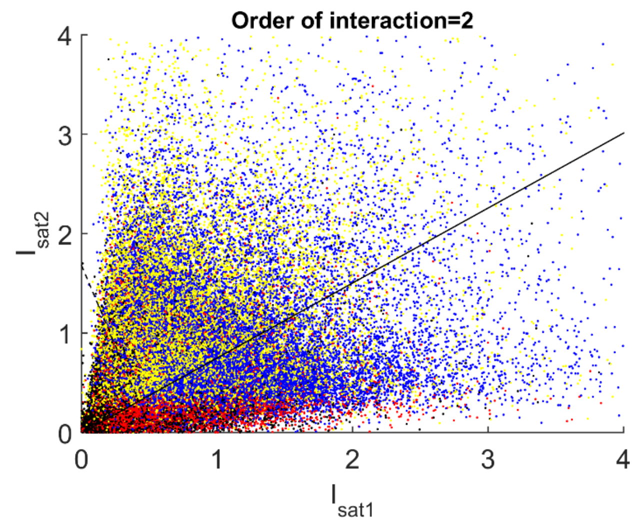


Next Order partition

- Looking to the time series in steps of $\Delta t = \tau_{decor}/2$, we color the point accordingly with the partition a point will be.

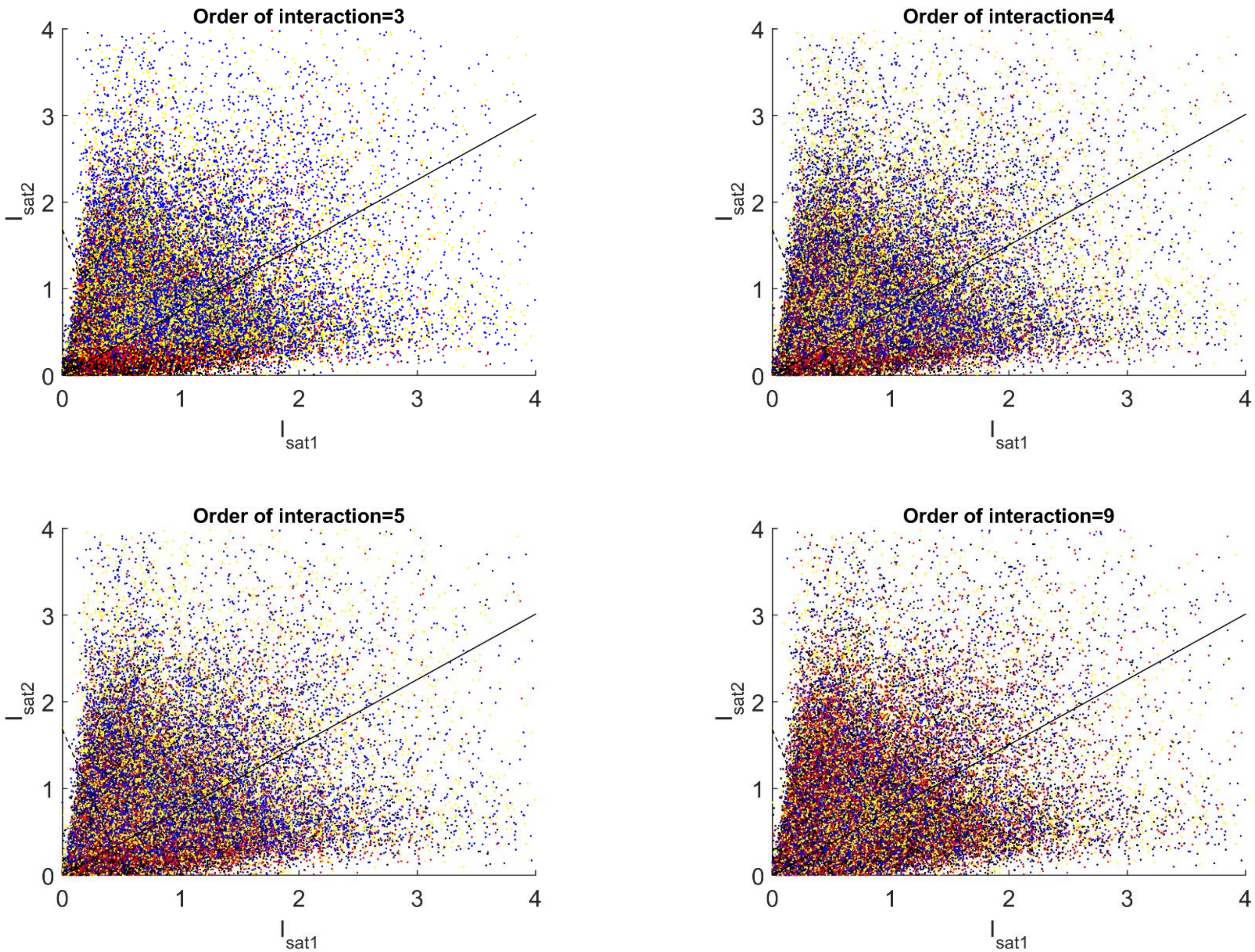


$\Delta t = \tau_{decor}/2$



The color represents in which partition a point will be after Δt.
Example: points in partition 4 have a high probability to be in the partition 2 after Δt, so lots of points in partition 4 (top) have blue color.

Orders n-1 (n-1 time intervals Δt):

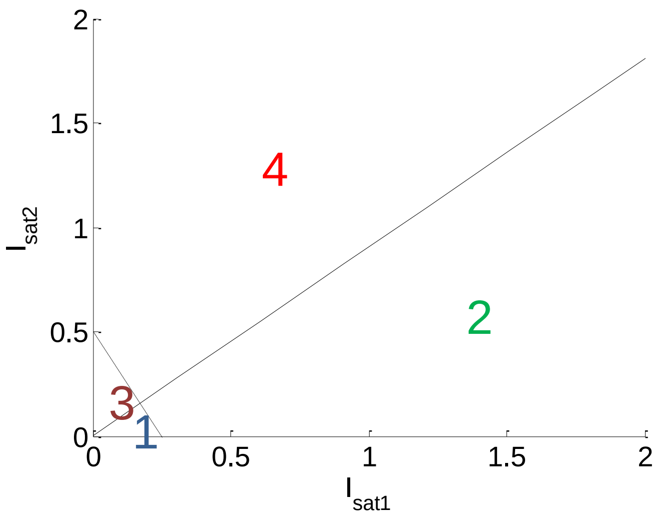


Probability matrix:

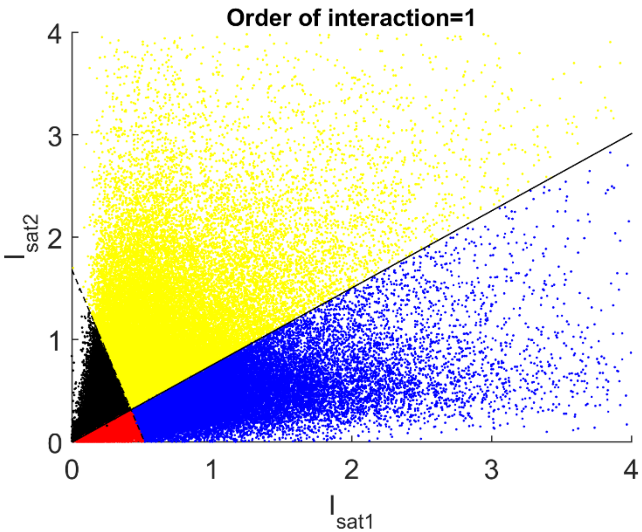
- Looking to the time series in steps of $\Delta t = \tau_{decor}/2$, we calculate the probability of a point in an partition be, after Δt, in another partition:

$$\boldsymbol{P}_n = \begin{bmatrix} P11 & P12 & P13 & P14 \\ P21 & P22 & P23 & P24 \\ P31 & P32 & P33 & P34 \\ P41 & P42 & P43 & P44 \end{bmatrix}$$

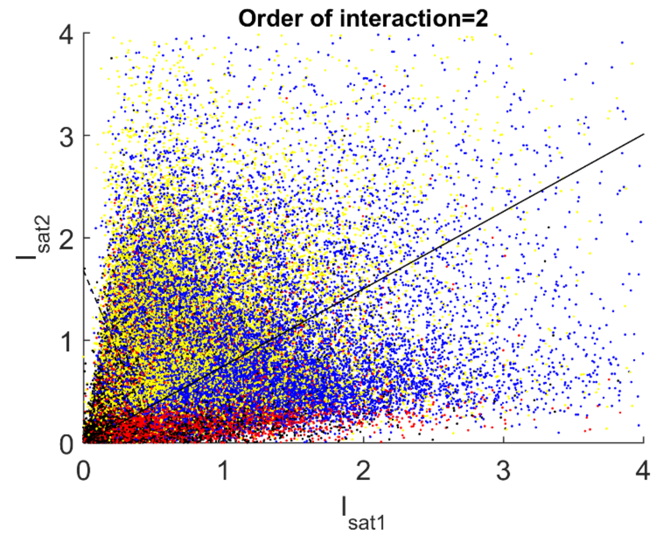
P12: Probability of a point in partition 1 be in partition 2, after n*Δt .



Probability matrix:



$\Delta t = \tau_{decor}/2$



$$\boldsymbol{P_1} = \begin{bmatrix} 0.5365 & 0.0474 & 0.3613 & 0.0549 \\ 0.2002 & 0.4636 & 0.0872 & 0.2490 \\ 0.2062 & 0.0944 & 0.5034 & 0.1960 \\ 0.0571 & 0.3946 & 0.0481 & 0.5001 \end{bmatrix}$$

Probability matrices:

$$P_1 = \begin{bmatrix} 0.5365 & 0.0474 & 0.3613 & 0.0549 \\ 0.2002 & 0.4636 & 0.0872 & 0.2490 \\ 0.2062 & 0.0944 & 0.5034 & 0.1960 \\ 0.0571 & 0.3946 & 0.0481 & 0.5001 \end{bmatrix}$$

$$P_2 = \begin{bmatrix} 0.4228 & 0.0894 & 0.3818 & 0.1060 \\ 0.2330 & 0.3422 & 0.1477 & 0.2771 \\ 0.2242 & 0.1684 & 0.3745 & 0.2329 \\ 0.1199 & 0.4000 & 0.0960 & 0.3840 \end{bmatrix}$$

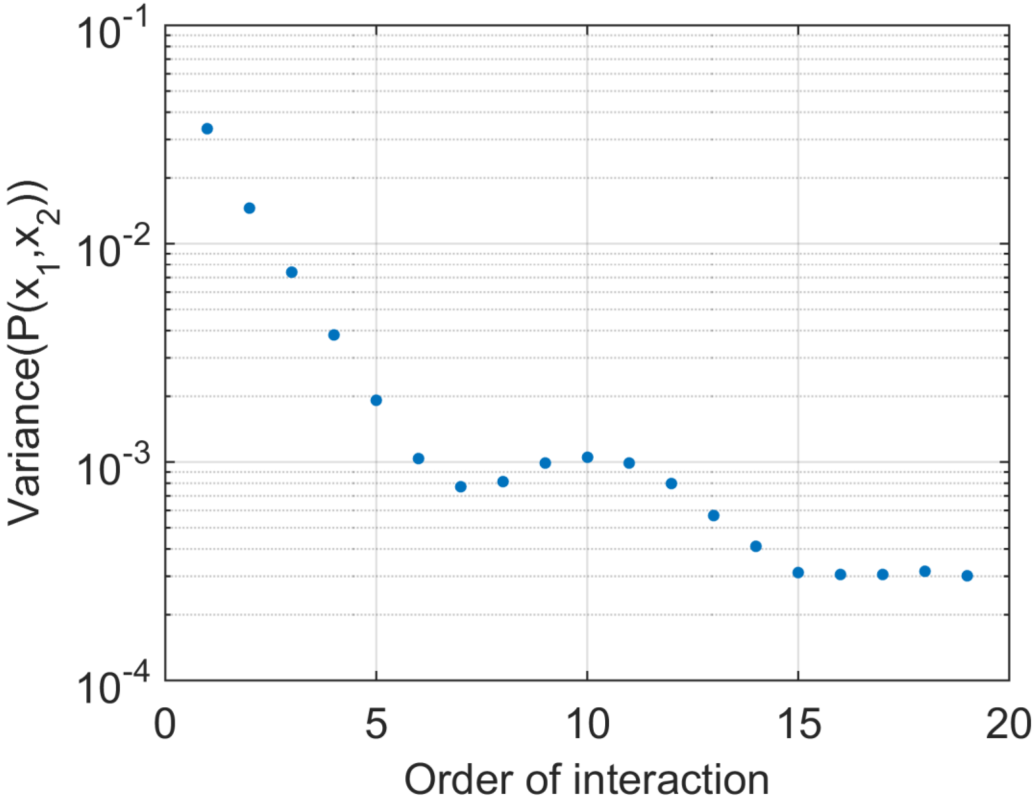
$$P_3 = \begin{bmatrix} 0.3652 & 0.1225 & 0.3719 & 0.1405 \\ 0.2501 & 0.3004 & 0.1860 & 0.2635 \\ 0.2239 & 0.2159 & 0.3085 & 0.2516 \\ 0.1609 & 0.3612 & 0.1336 & 0.3443 \end{bmatrix}$$

$$P_4 = \begin{bmatrix} 0.3286 & 0.1515 & 0.3519 & 0.1681 \\ 0.2550 & 0.2711 & 0.2184 & 0.2555 \\ 0.2257 & 0.2464 & 0.2668 & 0.2612 \\ 0.1907 & 0.3310 & 0.1629 & 0.3153 \end{bmatrix}$$

$$P_{15} = \begin{bmatrix} 0.2631 & 0.2284 & 0.2819 & 0.2267 \\ 0.2380 & 0.2631 & 0.2309 & 0.2681 \\ 0.2580 & 0.2436 & 0.2596 & 0.2388 \\ 0.2410 & 0.2649 & 0.2277 & 0.2664 \end{bmatrix}$$

When does the system becomes memoryless?

Probability matrices:

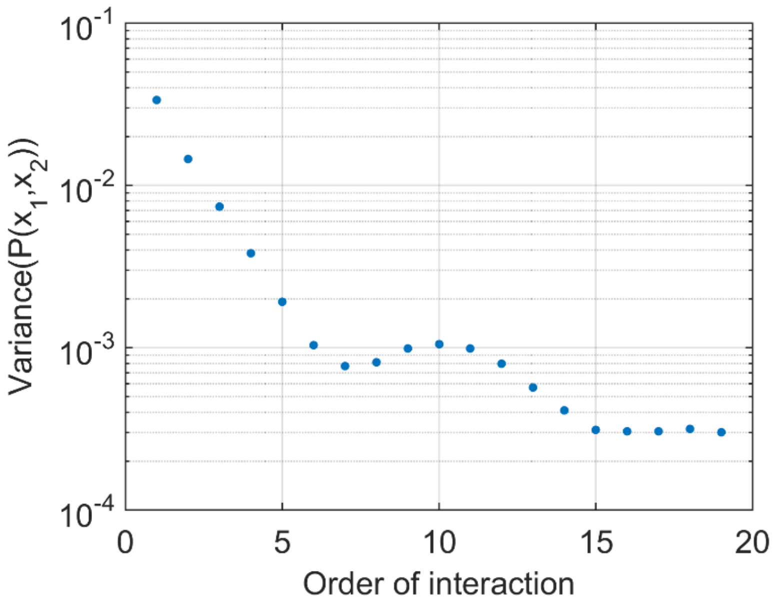


$$P_{15} = \begin{bmatrix} 0.2631 & 0.2284 & 0.2819 & 0.2267 \\ 0.2380 & 0.2631 & 0.2309 & 0.2681 \\ 0.2580 & 0.2436 & 0.2596 & 0.2388 \\ 0.2410 & 0.2649 & 0.2277 & 0.2664 \end{bmatrix}$$

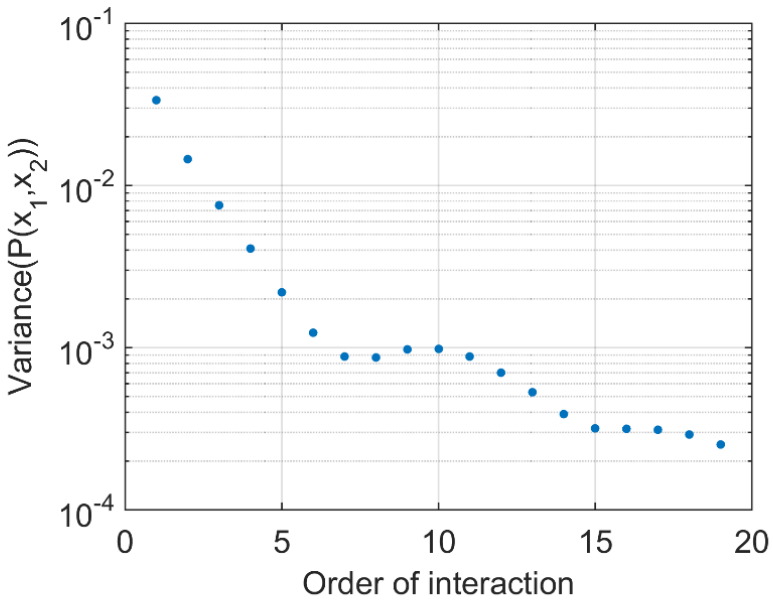
When does the system becomes memoryless?

Probability matrices:

R = 1.11m bias=14V

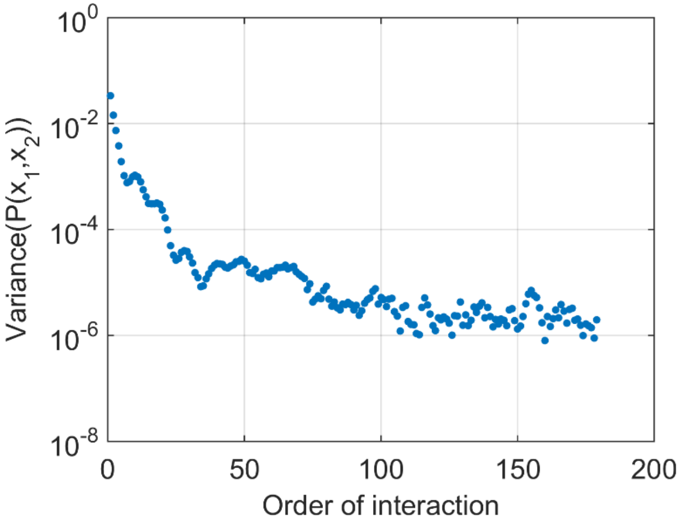


R = 1.11m bias=12V

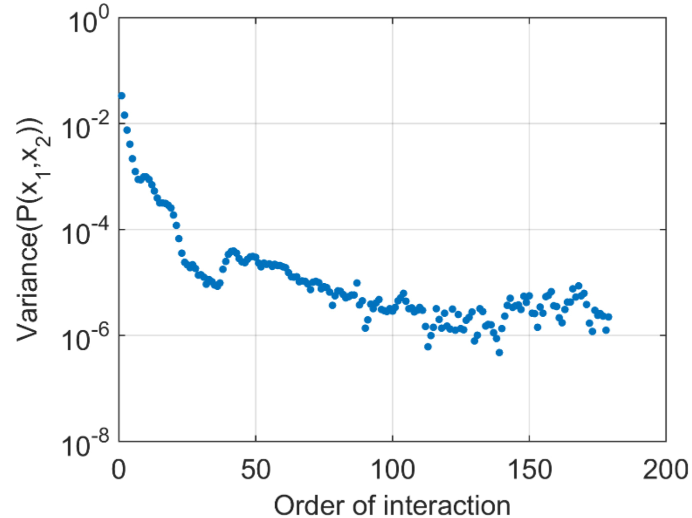


Probability matrices:

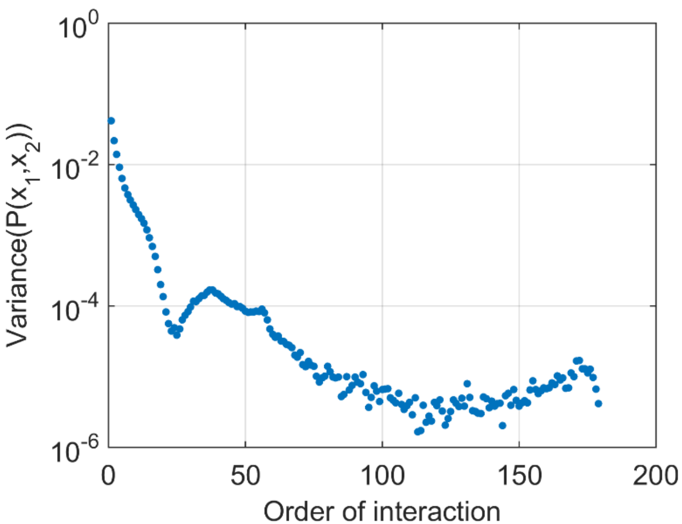
R = 1.11m bias=14V



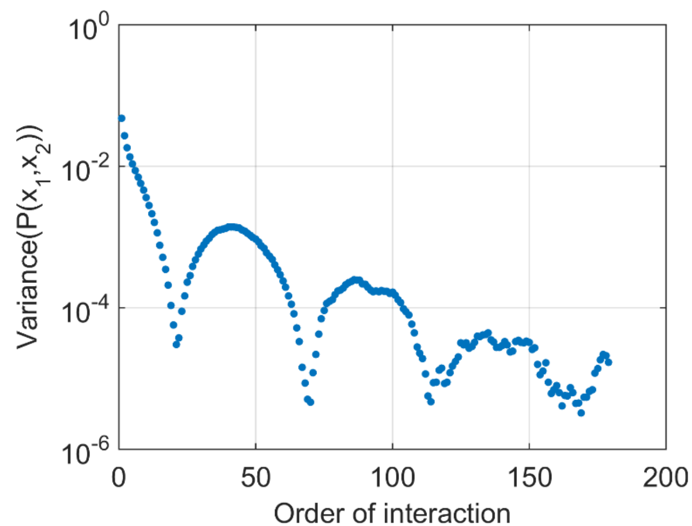
R = 1.11m bias=12V



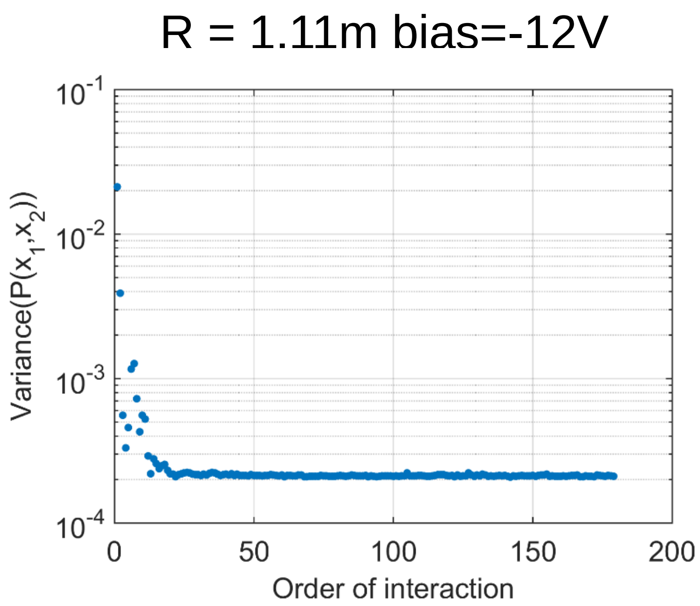
R = 1.11m bias=06V

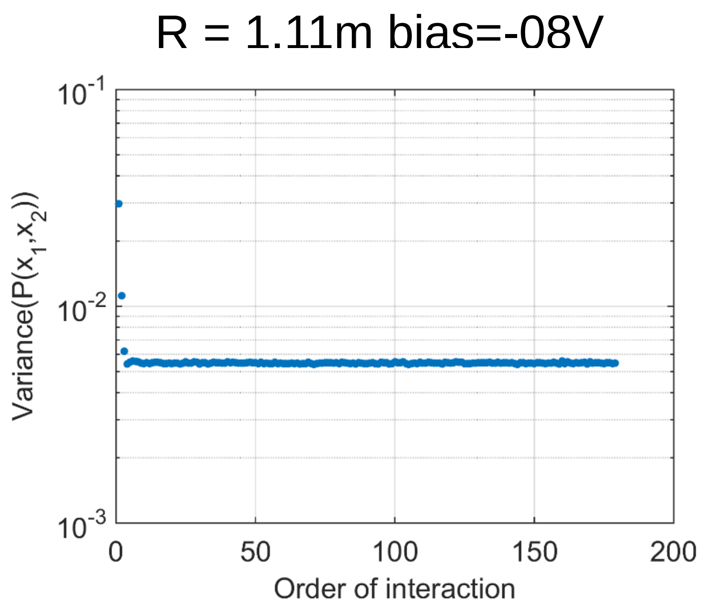


R = 1.11m bias=00V



Probability matrices:





5. Conclusions and Perspectives

- Turbulence and turbulent transport of particles in the plasma edge have been widely studied in the last decades by their relation to the magnetic plasma confinement in tokamaks.
- The Texas Helimak is a basic toroidal plasma machine, with a comprehensive system diagnostics and the ability to control the radial profile of the radial electric field through the imposition of an external electrical potential (bias).
- Due to its characteristics Helimak Texas is a very interesting machine to control turbulence and transport.
- Data from the ion saturation current were used to study the characteristics of turbulence.
- This analysis revealed that discharges with bias ≥ 0 present turbulence dominated by extreme events (bursts);

Conclusões e Perspectivas

- The value of the applied bias directly affects the occurrence of bursts, which are more frequent for higher values of bias.

- On the other hand the average shape of these events is unaffected by the external bias;

- A new approach to analyze plasma turbulence are in the firsts steppes with promising results;

Thanks.