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# TIME RESOLVED X-RAY MEASUREMENTS IN A SIMPLE MIRROR TRAP

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*Abstract*

The time-resolved characterization of the X-ray emission represents an innovative technique to investigate the heating mechanism of the worm/hot electron component in ECRIS devices. In this paper, the technique will be described and the results of an experimental campaign of measurements in order to characterize the X-rays emission of an axis-symmetric simple mirror trap will be showed.

## INTRODUCTION

The Electron Cyclotron Resonance Ion Sources (ECRIS) are used to produce charged ion beams at high intensity characterized by high stability and high reliability for accelerators and others applications both in nuclear physics and industrial area. Over the years, many studies have been conducted to understand the scaling of plasma parameters as function of tuning parameters, such as pumping wave power and frequency and magnetic field profiles. In particular, it was observed that the $B_{min}/B_{ECR}$ ratio, namely the gradient of the magnetic field, is one of the parameters that mainly generate instability and anisotropy in plasmas: a non-linear increase of X-ray fluxes has been observed.

In this work, we want to investigate the X-ray emission from the Flexible Plasma Trap (FTP) by means of a Hyper-Pure Germanium (HpGe) in time-resolved configuration.

## EXPERIMENTAL SETUP

The FTP, designed, developed and installed at INFN-LNS, allows the plasma characterization. The chamber is a cylindrical water-cooled copper vessel with an inner diameter of about 82 mm and a length of 260 mm. The plasma chamber is connected with a stainless-steel made “pre-chamber” in order to host the vacuum system and the diagnostics tools.

The external magnetic field used for ECR heating and plasma confinement is generated by means of three solenoids which allow tuning the magnetic field in function of the frequency. In particular, a simple magnetic mirror, a constant B field along the axis of the cylindrical discharge vessel and a magnetic beach configuration can be generated by tuning the current flowing in the coils. In this work we focused on the investigation of the simple mirror, with varying $B_{min}/B_{ECR}$ ratio. Moreover, FTP has three different microwaves system, one parallel and two perpendicular respect to the plasma chamber. Microwaves of axial injection are generated by a Travelling Wave Tube (TWT) operating in a range from 4 to 7 GHz. The perpendicular microwave launcher can work at 14 GHz and allow operating in double frequency (first and second frequency) mode [1]. Further information about the FPT can be found in reference [2].

The HpGe detector, located on the axial port of the vacuum chamber, as shown in Fig. 1, was used in order to investigate the X-ray emission from high energy electrons of the plasma or of those that hit the chamber walls.

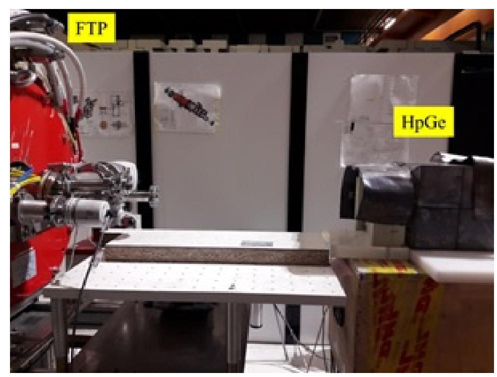


Figure 1: Experimental setup.

The HpGe consists of a 15 mm thick, 20 cm$^2$ detector that sits behind a 0.3 mm thick Be window. Its resolution at 122 keV is 0.61 keV. The detector is shielded with lead blocks of 2 cm thickness and $\phi$= 1 mm to avoid detecting x-rays scattered from the environmental material. The HpGe detects the radiation that pass mostly through the collimator of the vacuum vessel.

The detector was connected, at the same time, at the acquisition system MultiChannel Analyzer (MCA) and at the oscilloscope. In order to allow the time resolved X-ray spectroscopy, by means of an external trigger, the plasma was "switched on" for a duration of 40 ms and then it was "switched off". In Fig. 2 is shown a typical signal obtained from oscilloscope.

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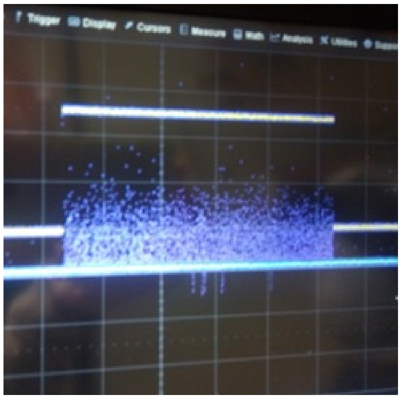

Figure 2: Typical spectrogram of X-ray emission in 40 ms from oscilloscope.

The time-resolved configuration has allowed to obtain preliminary information about the spectral X-ray emission as function of a time interval and to investigate the behaviour of X-ray flux with the increasing of time.

## RESULTS

The data were recorded at a power level of 80 W and at operating pressure in vacuum chamber of about 8x10$^{-5}$ mbar. Moreover, the X-ray emission was investigated at two different heating frequencies, 4.1 and 6.83 GHz and varying the Bmin/$B_{ECR}$ ratio from 0.56 to 1.02, namely setting the current of the injection and extraction coils and changing the current of the mid coils.

In standard configuration, it was observed that, at 6.8 GHz, for value Bmin/$B_{ECR}$ less than 0.83 the X-ray emitted is negligible and for Bmin/$B_{ECR}$ higher than 0.83 the rate increase suddenly; while, at 4.1 GHz, the rate of X-ray flux changes considerably for Bmin/$B_{ECR}$ > 1, as shown in Figs. 2 and 3.

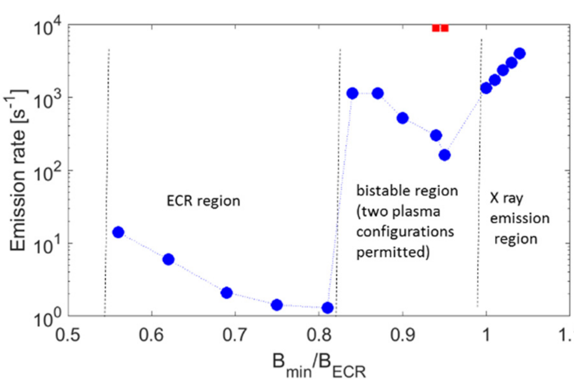


Figure 3: X-ray emission rate versus different simple mirror configurations at 6.83 GHz.

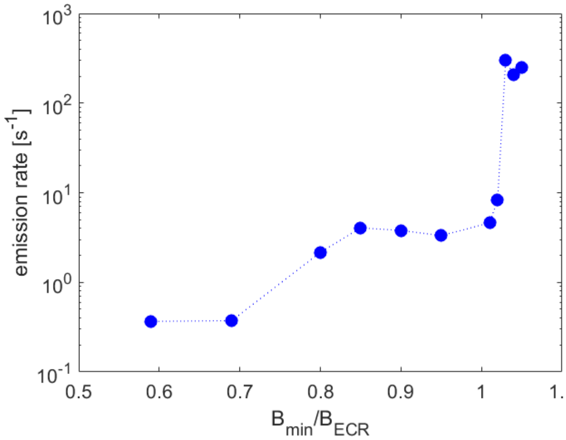


Figure 4: X-ray emission rate versus different simple mirror configurations at 4.1 GHz.

X-ray emission rate was also estimated in time-resolved configuration. In Figs. 5-7 are shown these rates in different plasma configuration: it is possible to observe that in the X-ray region emission (Bmin/$B_{ECR}$=1.01) the flux increase with time.

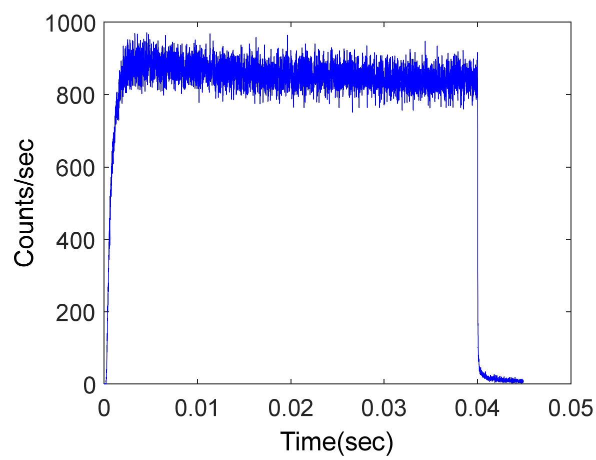


Figure 5: X-ray emission rate as function of time at 6.83 GHz and Bmin/$B_{ECR}$=0.95.

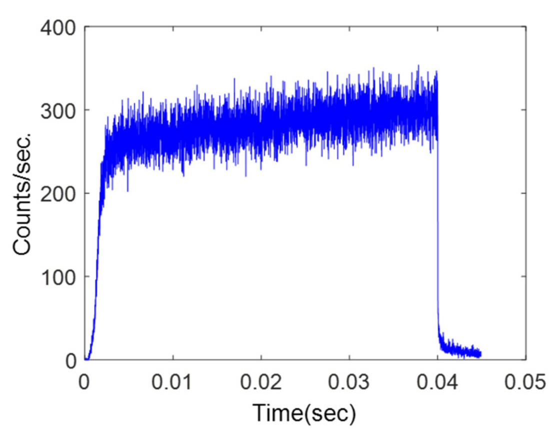


Figure 6: X-ray emission rate as function of time at 6.83 GHz and Bmin/$B_{ECR}$=1.01.

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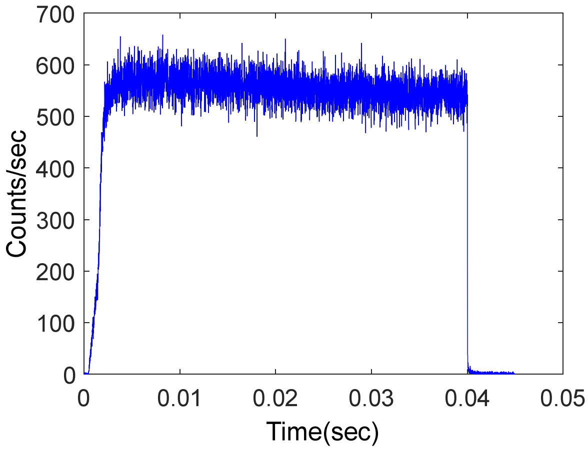


Figure 7: X-ray emission rate as function of time at 4.1 GHz and Bmin/$B_{ECR}$=1.04.

## REFERENCES


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