Characterization of ECR plasma by means of radial and axial X-ray diagnostics

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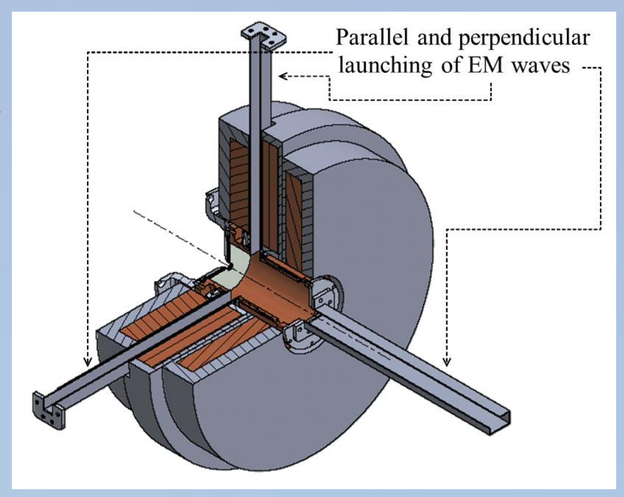
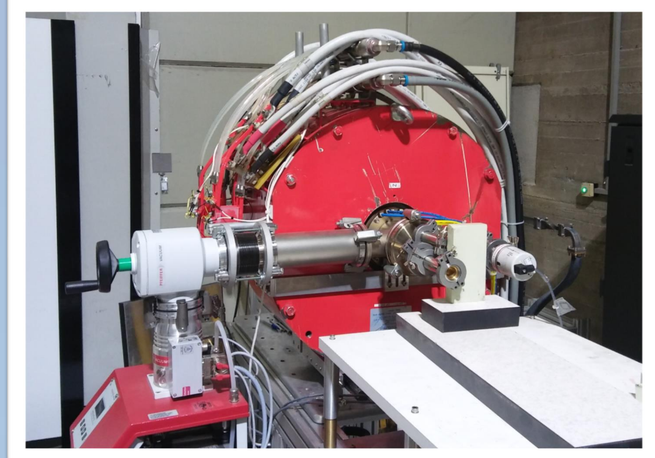
Abstract

This work presents the X -ray characterization of the plasma generated in a simple mirror axis symmetric trap as a function of the magnetic field profile. A Si-Pin detector has been used to characterize warm electron population in axial and radial directions at two different operating frequencies: 4.1 GHz and 6.8 GHz. Moreover, the hot electrons emitted in axial direction has been measured by means of a HyperPure Germanium (HpGe) detector. Results show that X-ray emission is not homogenous and its homogeneity and temperature depends strongly on the magnetic field profile.

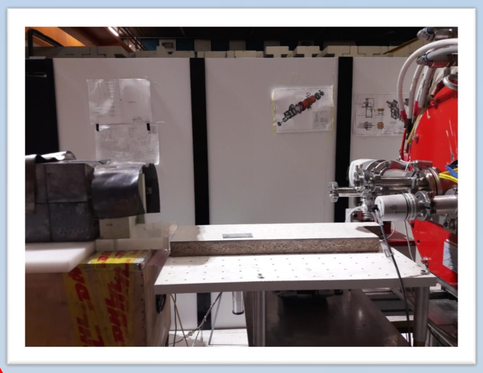


Flexible Plasma Trap

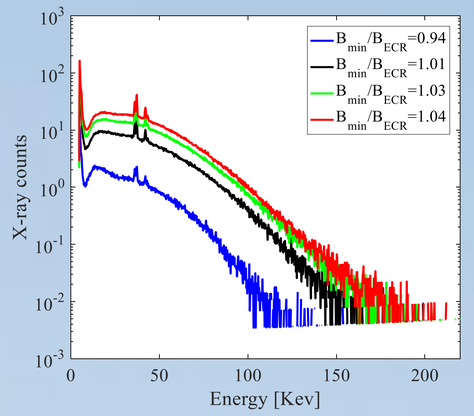
FPT is a test bench for plasma diagnostics and development of new sources, operating at INFN-LNS. Three solenoids generate different magnetic profiles (off-resonance, simple mirror and magnetic beach configuration) and allow to tune the magnetic field value in function of the frequency. FPT has three different microwave systems, one parallel and two perpendicular respect to the plasma chamber. The axial injection operates from 4 to 7 GHz. The perpendicular microwave launcher can work at 14 GHz and allow to operate in double frequency (first and second frequency) mode.
The water-cooled copper plasma chamber is 260.1 mm length and its inner diameter is about 82 mm. A stainless-steel vacuum chamber, is connected to the plasma chamber to host the vacuum system and the diagnostic tools.

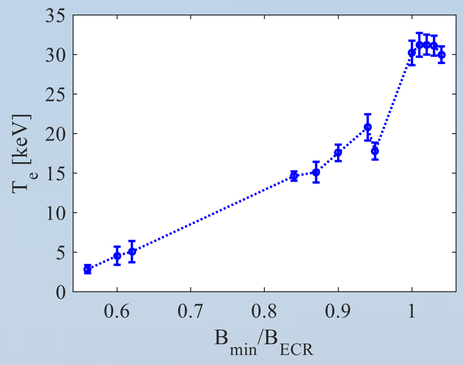


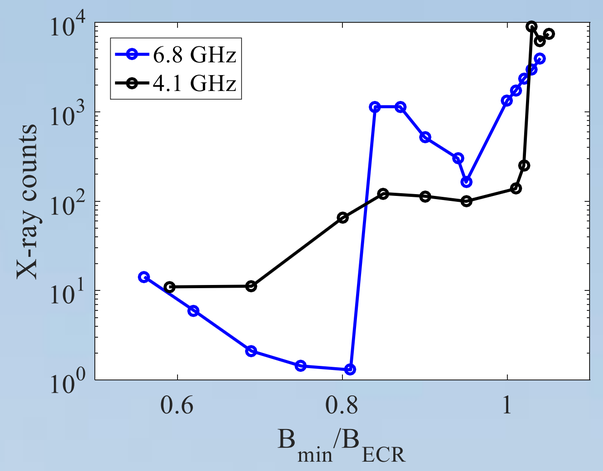
HyperPure Germanium detector and CCD Camera



The Germanium resolution at 122 keV is 0.61 keV



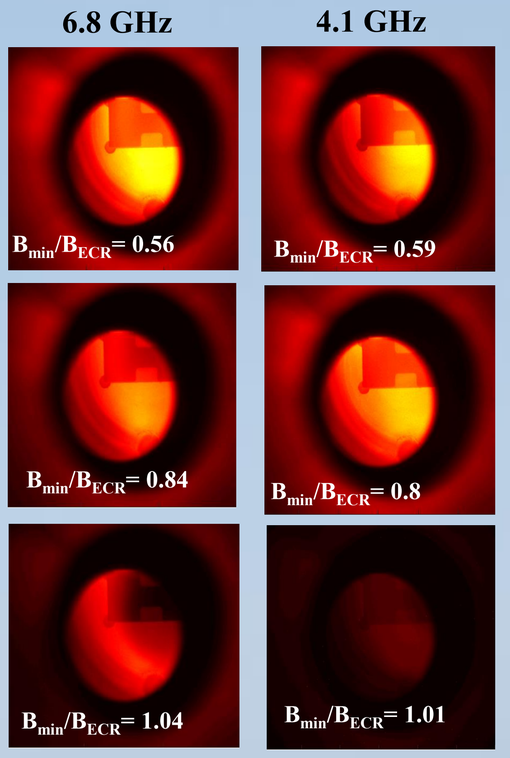




X-ray diagnostic

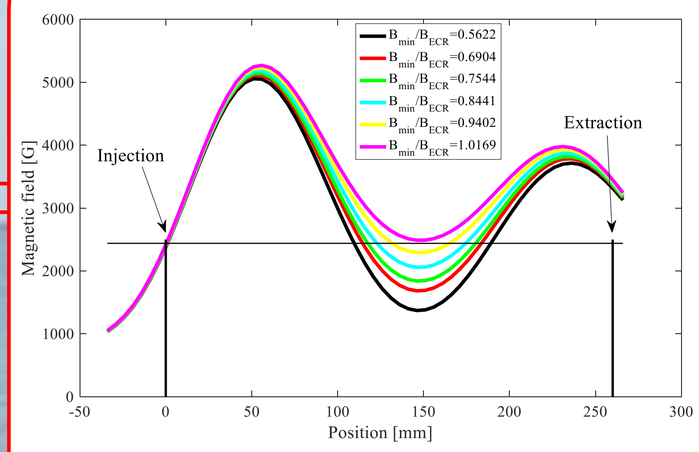
The bremsstrahlung emission is divided in two region for 6.8 GHz:

- High X-rays counts
- Low X-rays counts

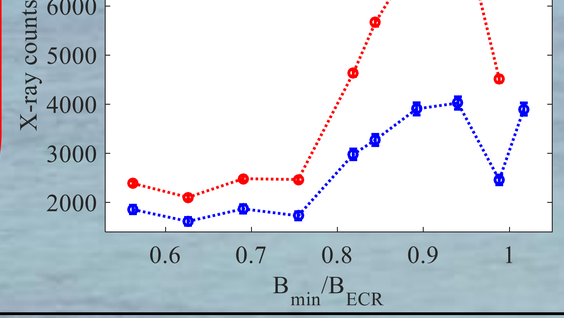


All data were recorded at a **power level** of **80 W** and the typical operating **pressure** in vacuum chamber is about $8 \cdot 10^{-5}\, mbar$.

Simple mirror configurations

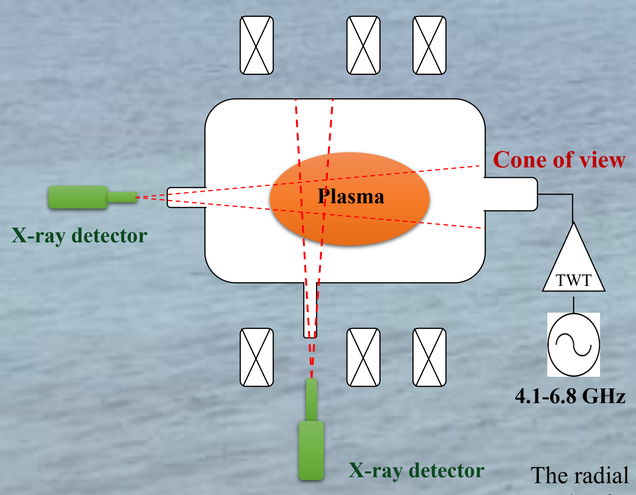


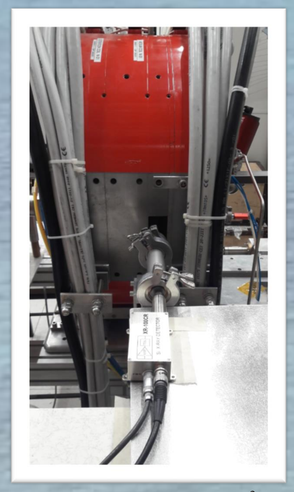
Simple mirror configurations used at 6.8 GHz as heating frequency. The change in mid coil current allowed to modify the ratio along the plasma chamber axis from 0.56 to 1.02 (B_{ECR} = 2440 G at 6.8 GHz).



The x-ray production and electron temperature depend on the magnetic configuration: when B_{min}/B_{ECR} ratio is ≈ 0.8 the plasmas start to be unstable

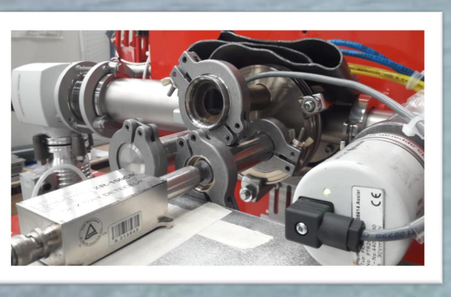
Si-Pin detectors





All raw data have been corrected for detector intrinsic efficiencies, which include the correction for the beryllium window, the Kapton foil for vacuum break, and the air attenuation.

The magnetic field gradient becomes lower in a large part of the ECR surface and the electrons gain more energy for a single crossing of the resonance. These hot electrons escape from the magnetic confinement and raise the rate of bremsstrahlung emission.



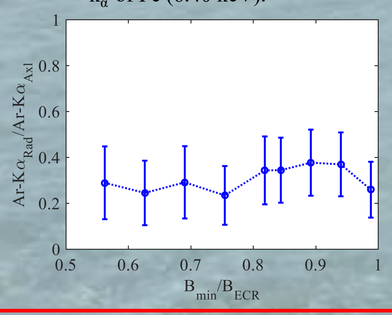
The Si-Pin resolution at 5.9 keV is about 200 eV.

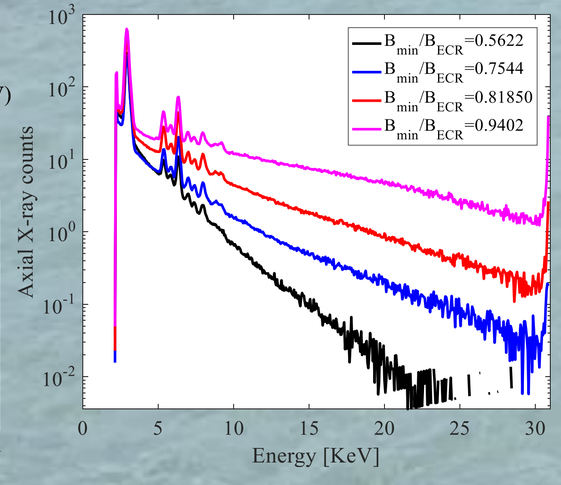
The radial spectrum has:

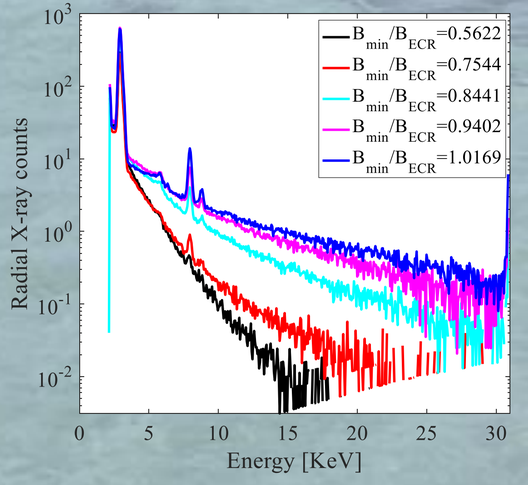
- k_α of Ar (2.96 keV),
- k_α and k_β of Cu (8.05 and 8.9 KeV)

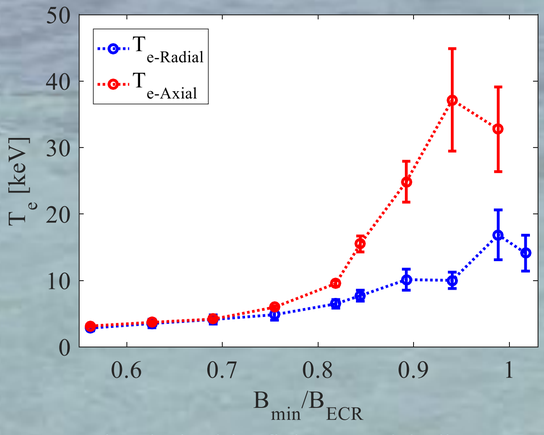
The axial spectrum has also:

- k_α of Cr (5.41 keV)
- k_α of Fe (6.40 keV).









T_e can be obtained by fitting a straight line to experimental data in a semilogarithmic plot over a selected range of energy