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The multi-detectors system of the PANDORA facility for β-decay investigation in astrophysical conditions: focus on the full-field pin-hole CCD system for X-ray imaging and space-resolved spectroscopy

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PANDORA (Plasmas for Astrophysics Nuclear Decays Observation and Radiation for Archaeometry) is an INFN project aiming at measuring, for the first time, possible variations of in-plasma β-decay lifetimes in isotopes of astrophysical interest, as a function of thermodynamical conditions of the in-laboratory controlled plasma environment. Theoretical predictions say that the ionization state can dramatically modify the β-decay lifetime (several orders of magnitude). The PANDORA experimental approach consists of confining a plasma able to mimic specific stellar-like conditions, thus measuring the evolution of the nuclear lifetime as a function of plasma parameters. The density and temperature of radionuclides can be maintained in dynamical equilibrium even for weeks when diffused in a buffer plasma confined by a B-minimum superconducting magnetic trap, now under construction. The β-decay events will be tagged by detecting the γ-ray emitted by the daughter nuclei by an array of 14 HPGe detectors placed around the magnetic trap. In this frame, plasma parameters have to be continuously monitored online: in PANDORA they will be measured through an innovative, non-invasive multi-diagnostic system, including high resolution time- and space-resolved X-ray analysis, which will work synergically with a γ-rays detection system. In this contribution we will describe this multi-diagnostics system with a focus on the powerful technique based on spatially resolved high resolution X-ray spectroscopy using a pin-hole X-ray camera setup operating in the 0.5 - 20 keV domain. The achieved spatial and energy resolutions are 500 µm and 230 eV at 8 keV, respectively. An analysis algorithm has been specifically developed to obtain SPhC (Single Photon-Counted) images and local plasma emission spectrum in High-Dynamic-Range (HDR) mode. Thus, investigations of image regions where the emissivity can change by even orders of magnitude are now possible. Post-processing analysis is also able to remove readout noise, which is often observable and dominant at very low exposure times (ms). Several measurements were made in compact magnetic plasma traps, allowing quantitative and absolute evaluation of local emissivity, and the elemental analysis was carried out. Recently new models have been developed to obtain spatially resolved plasma parameters from the experimental spectra, and the first local measurements of the electron density and temperatures have been provided. In addition, fast X-ray shutters and trigger systems have been tested and will be routinely implemented to simultaneously carry out space- and time-resolved spectroscopy during transients, stable and turbulent plasma regimes (in the ms timescale), useful to study kinetic plasma turbulences in laboratory plasmas, such as the cyclotron maser instability causing radio and X-ray bursts emission in astrophysical objects.

Summary

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