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Advancing Plasma Analysis: An Integrated X-ray Spectroscopy System Utilizing GEM and Timepix3 Technology for Soft and Hard X-Rays, and Gamma Radiation Detection

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X-ray emission measurements offer profound insights into plasma behavior in both spatial and temporal contexts. These findings are critical in understanding various plasma parameters, including ion and electron temperatures, electron density, impurity concentration, and more. We propose an innovative X-ray spectroscopy diagnostic system that integrates a robust, noise-free Gas Electron Multiplier (GEM) detector for sensitive Soft X-ray detection and a compact, solid-state silicon Timepix3 (TPX3) detector for Hard X-ray and gamma radiation detection. The GEM detector read-out has been equipped with a PCB layout having four rows with 64 pads, each one having an area of 1.5×20 mm^2. In this configuration, it offers not only a wide active area (10×10 cm^2) for 2D measurements on Soft-X rays (2-20 keV) through a cathode Mylar window but also 1-D measurements on higher X-ray energies (2-50 keV) through two symmetric side Kapton windows on the opposite ends of the active gas region. It features high sensitivity, a wide dynamic range, excellent energy resolution, high temporal resolution, significant resistance to electromagnetic disturbances and high neutron and gamma background, despite its limited pixel count. The TPX3 detector's silicon-based, pixelated sensor (pixel dimensions 55 µm × 55 µm; active area 14 mm $\times$ 14 mm) enables ionizing particle or radiation identification through morphological particle track analysis. We used the GEM detector in a 1-D configuration leveraging the full depth of the gas (10 cm) with an energy resolution of about 25%. The more energetic part of the radiation beam is not absorbed in GEM gas volume and exits through the downstream side window. Consequently, the TPX3 detector is situated side-on at the GEM detector's exit, harnessing the full size of the silicon sensor (14 mm), in contrast to the mere 300 µm front face. This positioning allows the TPX3 detector to identify Hard X-rays (50-500 keV) through a suitable morphological analysis and gamma rays in the 0.5-10 MeV range with a different trace treatment inside the detector. The tandem operation of the GEM and TPX3 detectors facilitates a spectroscopic analysis of radiation along the same line of sight. Both detectors have been also tested in the Frascati Neutron Generator (FNG) with 14 MeV neutrons up to 10^7 n/s·cm^2, suggesting potential use in experiments or facilities with high radiative (n, gamma) background. For such scenarios, we propose including a diamond TPX3 in the diagnostic system for fast neutron background monitoring.

Summary

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