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A Large-Volume, Extended Field-of-View TPC for X-Ray Polarimetry

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We present the design, development, and initial performance of a large-volume, wide field-of-view Time Projection Chamber (TPC) tailored for X-ray polarimetry. The instrument employs a triple-GEM detector with an optical readout system, using a scientific CMOS (sCMOS) camera to capture the secondary scintillation light produced during gas amplification. Initially optimized for directional Dark Matter searches, this system has been successfully adapted to measure the polarization of X-rays, opening a new observational window into the high-energy universe.

X-ray polarimetry provides critical insights into the magnetic fields, geometries, and emission mechanisms of cosmic sources such as black holes, neutron stars, and supernova remnants by complementing traditional intensity and energy measurements with polarization data. The prototype TPC features a cylindrical active volume (radius 3.7 cm, height 5 cm) and was tested at the INAF-IAPS calibration facility in Rome, Tor Vergata. Tests suggested complete reconstruction of photoelectron tracks in the 10–60 keV range, with angular resolutions down to 15° and energy resolutions between 10–15% over the 5–45 keV range. Analysis of electron tracks obtained using a collimated ^{90}Sr source showed angular resolutions better than 30° for energies above 10 keV and below 20° for energies between 20 and 60 keV, with possible modulation factors reaching up 0.6 and 0.8, respectively. Preliminary results from the first calibration using a fully polarized 17 keV X-ray beam at the INAF facility are promising. They suggest a modulation factor greater than 0.4 can be achieved at this energy.

This innovative TPC design not only extends the energy sensitivity of X-ray polarimetry but also enhances the capability to observe rapid transient phenomena, such as Gamma Ray Bursts and solar flares. Future developments will explore alternative gas mixtures to optimize the photoelectric cross-section, with planned experiments using fully polarized X-ray beams at the INAF calibration facility.

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