Performance test of TPC Polarimeter for cosmic X-ray sources at BNL NSLS-1

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Cosmic X-ray polarimetry is believed to be a powerful measurement technique for studying the physics in extreme environments such as strong gravitational fields and magnetic fields in the universe. However, soft X-ray polarization has not succeeded so far except for a few detections in the 1970's [1]. To study such an unexploited field, NASA and RIKEN have been developing an X-ray polarimeter that employs the Time Projection Chamber (TPC) technique[2]. In this progress report, we discuss the performance test of a TPC polarimeter with a new Read Out Board (ROB) design[3].

When an incident X-ray interacts with a gas atom, a photoelectron is ejected preferentially in the direction of the electric field vector of the incident photon according to a cosine^2 probability distribution. Thus, we can determine the polarization degree and the phase by obtaining a track image and initial direction of the photoelectron. A schematic view of TPC polarimeter is shown in Fig 1. To ensure high efficiency for the polarization signal, the charge detection plane of the TPC polarimeter consists of the Gas Electron Multiplier (GEM) designed by RIKEN[4] mounted over strip anodes parallel to the incident X-rays. Two-dimensional images of photoelectron are created using a one-dimensional strip readout and by timing the arrival of charge[2]. For a small satellite mission of cosmic X-ray polarimetry, we have proposed two different ROB designs. One design uses two gold-plated titanium frames with "tongue in groove" to secure the strips under tension[3]. The performance of the polarimeter using this type of ROB has been verified and meets all mission requirements[5]. To reduce cost and risk by further simplifying the assembly more, the other design one has used epoxy adhesives to hold the strips under tension to the lower frame.

We carried out the performance test for the polarimeter at the Brookhaven National Laboratory (BNL) Synchrotron Light Source-1 facility in September 2014. The polarimeter was filled with 190 torr dimethyl ether (DME). To make the pixels of the track image square-shaped, the electrical drift region was selected as 196 V/cm, which is the drift velocity equal to the 121 μm divided by the 50 ns sampling time. The transfer field between the GEM and the ROB was selected as 660 V/cm considering the collection efficiency of the charge. The detector was irradiated with liner-polarized monochromatic X-rays at eight energy bands. The total number of the events is 5×10^4 for individual measurement. Further, to calibrate the polarimeter, we also acquired 2.7 keV unpolarized events.

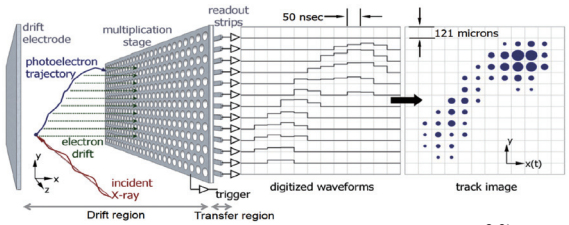

Fig. 1. Schematic view of the TPC polarimeter[2,3]

Fig.2 shows the derived modulation curves for three energy bands and the 2.7 keV unpolarized data at 8 mm from GEM, which corresponds to the detector optical axis. The results have subtracted the pedestal and common mode noise and deconvolved the electronics response. The S/N achieved 5 σ levels. To correct the asymmetry caused by the difference of the drift velocity between the drift and the transfer region, the results are corrected using Gaussian convolution in the time axis. The Gaussian σ value is 46 μm which is optimized using the 2.7 keV unpolaraized data[5]. As an indicator of the polarization sensitivity, we introduce a modulation factor μ , which is defined as

$$\mu = (f_{max} - f_{min}) / (f_{max} + f_{min}),$$

where f_{max} and f_{min} are maximum and minimum values of the modulation curve, respectively. The derived modulation factors of 2.7 keV, 4.5 keV, and 6.4 keV are 21.3±0.6%, 37.9±0.6%, and 46.6±0.6%, respectively. The results are consistent with previous ROB design[5] and meet the measurement requirement. The estimation of the systematic error for the detector position is still under discussion.

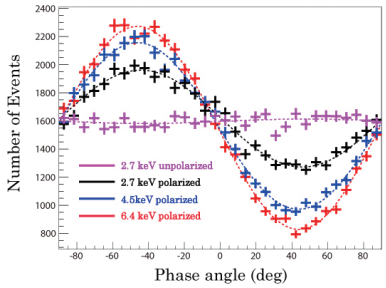

Fig. 2. Modulation at three energy bands measured at BNL using TPC polarimeter.

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