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Performance of Hard X-ray Polarimeter: PHENEX

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Introduction

We have been developing a hard X-ray polarimeter to open a new window for hard X-ray astronomy[1]. The name of the project is called as PHENEX (Polarimetry for High ENErgy X rays). The PHENEX polarimeter is a Compton-scattering-type polarimeter sensitive in the energy range from 40 keV to 200 keV and is constructed from an array of identical "unit counters" described below. Constructing the flight model with four unit counters surrounded by active shields, we have carried out balloon-borne experiment in Jun.13, 2006 to preliminarily observe the polarization of the Crab Nebula in hard X-ray band[2]. Though the PHENEX polarimeter operates well on the observation, the attitude control system did not function correctly and the line of the sight wandered around the Crab Nebula. Even so we succeeded in observing it for about one hour. However, the hard X rays from the Crab Nebula had entered to the PHENEX polarimeter from the slant. Therefore it is necessary for the data analysis to investigate the response of the PHENEX polarimeter for the slant injection in detail. So we have carried out the experiments for the slant injection to the PHENEX polarimeter at BL14A in KEK. We will report the results of the experiments in this paper.

Unit Counter

The unit counter consists of 36 (6x6) pieces of plastic scintillator surrounded by 28 pieces of CsI(Tl) scintillator, all read out by a 64-channel multianode photomultiplier (MAPMT) developed by HAMAMATSU Photonics Inc. The Figure.1 shows a schematic view for the unit counter. The pixel size of the multianode photomultiplier is 6.0 x6.0 mm^2 and the size of the scintillators is 5.5x5.5x40 mm^3 each. Hard X rays entering one of the plastic scintillators are Compton scattered and then absorbed by one of the surrounding CsI(Tl) scintillators. The azimuthal scattering angle depends on the polarization direction of the incident hard X rays. Since these scintillators are segmented, the 2-dimensional scattering direction can be measured and hence the information on the polarization of the incident hard X rays can be obtained. The instrument field of view is constrained to 4.8 degrees (FWHM) by a collimator made of 1-mm-thick molybdenum. The side of the unit counter is covered by graded passive shields made of Pb (2mm thickness) and Sn (1mm thickness). Each energy deposit in the plastic and CsI scintillators is read out by the MAPMT, and the signals from each pixel are fed through charge-sensitive preamplifiers and shaping amplifiers to an Analog to Digital Conversion (ADC) system for digitization.

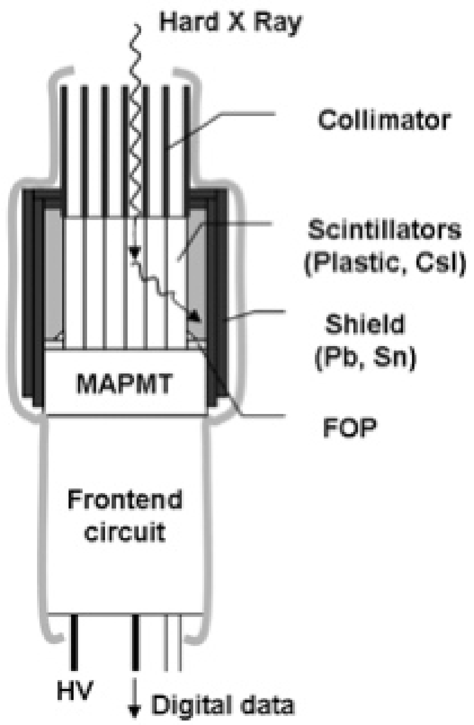

Figure 1: The schematic view of the unit counter. It consists of 36 plastic scintillators and 28 CsI(Tl) scintillators. The incident hard X ray is scattered by one of the plastic scintillator and then is absorbed by one of the CsI(Tl) scintillator. By the 2-dimensional scattering direction, the information on the polarization can be obtained.

In the previous experiments at BL14A, we measured the detection efficiency and the modulation factor in the case that polarized beam are injected with the incident angle of 0 degree. As the results, the unit counter can obtain the detection efficiency of 20% and the modulation factor of 53% at 80 keV, respectively[2].

Experiment of slant injection

To investigate the response of slant injection, experiments were carried out. The Figure.2 is the picture of the experimental setup. The beam is collimated to 1 mm^2 with the collimator and injected to the unit counter. The injection position is adjusted by the x-stage and y-stage. On the injection, the unit counter is rotated around the central axis of the unit counter to reduce a spurious modulation due to the individual difference of scintillators. The central axis is inclined with the beam axis at 1.5 degrees. The beam intensity is monitored by a photodiode detector at realtime. The events are acquired by VME system when the signal from any one of the CsI(Tl) scintillator is higher than a certain threshold level. On offline analysis, the coincidence events between one plastic scintillator and one CsI(Tl) are extracted.

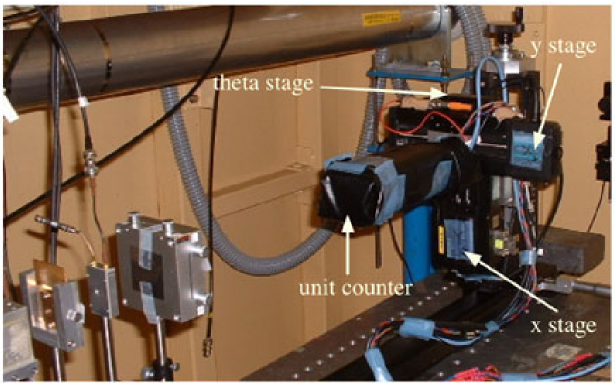

Figure 2: The picture of the experimental setup. The installed x-stage and y-stage are used to adjust the injection point. The installed theta stage is used to rotate the unit counter around the central axis of the unit counter. The central axis is inclined with the beam axis at 1 degree.

For six injection positions shown in Figure.3, the data were acquired and each modulation pattern for scattering angle was analyzed. After each analysis, the whole modulation pattern was investigated which would be obtained by uniform injection for the 36 plastic scintillators. The result are shown in Figure.4. The x axis and the y axis correspond to the scattering angle and the counts, respectively. As the polarization direction of the beam is 90 degrees or 270 degrees, the counts for 0 degree and 180 degrees are larger than those for 90 degrees and 270 degrees. In this figure, the difference of counts for 0 degree and 180 degrees is observed. It is due to the effects of the slant injection. By the results, we recognized that it is necessary to modify the effects for the acquired data with balloon-borne experiments. So we are developing a simulation program with EGS4 (Electron Gamma-ray Simulation Version4) which the slant injection is considered. In near future, we will present the results.

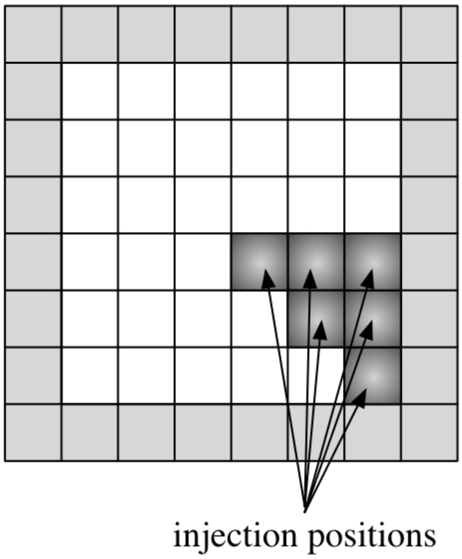

Figure 3: The beam is injected to the marked six positions. As the six positions are representatives for 36 plastic scintillators, we can investigate the total modulation pattern from the data of each modulation pattern.

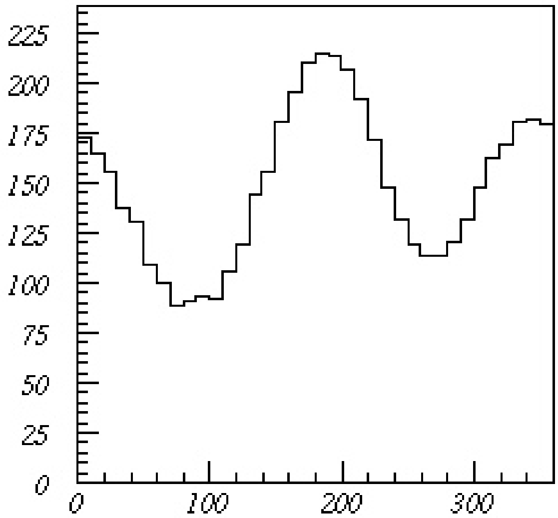

Figure 4: This figure shows the modulation pattern for the slant injection of 1.5 degrees.The x axis and the y axis correspond to the scattering angle and the counts, respectively. The difference of the counts for 0 degree and 180 degrees is due to the effects of the slant injection.

References

[1] T. Suzuki et al. JJAP Vol.45 No.1A pp274-278 (2006)
[2] Y. Kishimoto et al. IEEE Nucl. Sci. (2007) To appear