Proportional Counter with 7 μm Carbon Fiber and Detection of X-ray Polarization

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Abstract:
We report the simple X-ray polarimeter, using one dimensional position sensitive proportional counter (1DPSPC) with a thin anode wire. One of the methods to detect the X-ray polarization is measuring the distribution size of photo-electrons in gas. To observe the expansion of photo-electron cloud, a gas chamber needs to have an enough position resolution. The position resolution of 1DPSPC depends on the resistance noise of anode wire. To improve the position resolution, we selected carbon fiber of 7um diameter for anode. In this poster, we present a successful formula of position resolution for the obtained the data, and the performance of the detector as an X-ray polarimeter.

1. Improvement of Position Resolution of PSPC with a Thin Carbon Fiber

The position resolution of PSPC is better with a higher resistance anode. We compared the performance of 2 carbon fibers with different width. The fundamental properties are shown in Table 1. Both carbon fibers are manufactured by Japan Graphite. Figure 1 shows the configuration of our experiment. We used the gas of Argon and Methane(10%) mixture, and operated the PSPC with gas gain of 10^3 to $5x10^4$. We irradiated the monochromatic X-ray beam to the PSPC and obtained good energy resolutions as shown in Figure2.

Name	Diameter [μm]	Resistance [kΩ/cm]	Strength [gW]
10u	10	1.0 ±0.1	28.1 ±4.0
7u	7	6.5 ±1.1	8.7 ±2.4

Table 1. We selected 2 thin carbon fibers. This table show the diameter, resistance and strength. The 10u fiber was used for HETE-2 WXM[1] and MAXI GSC[2].

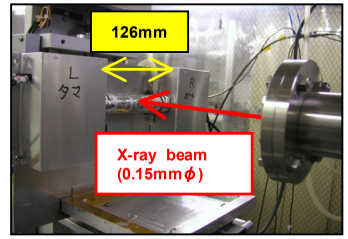


Figure 1. Configuration of our experiment at RIKEN

The position resolution (ΔPres) was different even at the same gas gain as shown in Figure3. We try to describe a formula of ΔPres. The ΔPres depends on the resistance noise (Johnson noise) and the size of photo-electron cloud. We take these factors into the formula as,

$$\Delta Pres = 2.35(\sigma_j^2+\sigma_e^2+\sigma_c^2)^{1/2} + W \qquad (1)$$

where σ_j is the resistance noise factor, σ_e is the Poisson noise factor, σ_c is the size of photo-electron cloud[3] and W is the X-ray beam width.

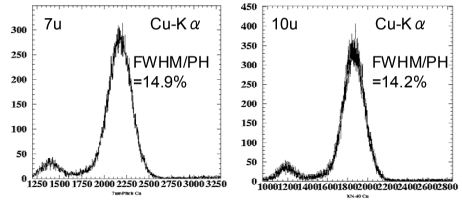


Figure2. The Cu-K α spectrum at the same gas gain.

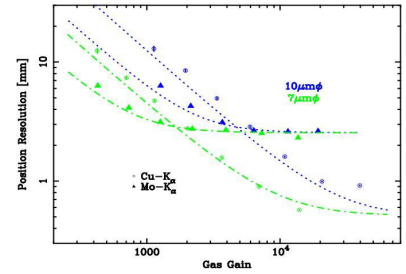
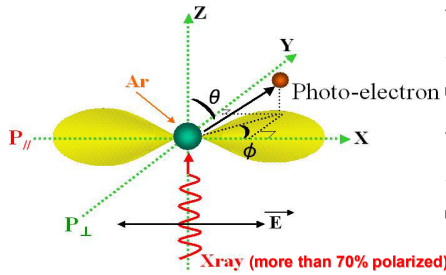
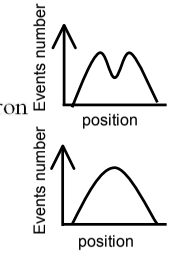


Figure3. The marks show our experimental results and lines present calculation by formula (1).

2. Application for an X-ray Polarimeter of 7 μmϕ carbon-fiber PSPC

The PSPC with 7 μmϕ fiber showed good position resolution. We test this PSPC to detect the X-ray polarization. A simple method to detect the X-ray polarization is to measure the precise size of ejected photoelectron in the perpendicular plane to incoming X-ray. In case the anode is set parallel to the electric vector of X-ray, the 1dimentional distribution of the electrons in PSPC is expected to have 2 bumps (Figure4). Whereas, 1 bump distribution is to be observed when the anode is perpendicular to the electric vector. To confirm this prediction, we irradiated the >70% polarized X-ray beam to the 7u PSPC at KEK photon factory BL14A. The experimental set up is shown in Figure5.





Expected collected electron distribution at $P_{//}$ position.

Expected collected electron distribution at $P_{\perp}$ position.

Figure4. Photoelectron tends to be ejected at the same direction of electric vector of incoming photon. We set the detector in X-Y plane to measure the size of photoelectrons. When we set the anodes along X-axis we expect two bumps in position distribution. On the other hand, when we set it along Y-axis we expect one bump. Thus we can measure X-ray polarization from the position distribution.

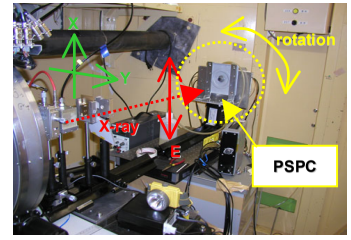


Figure5. Our experimental set up at KEK photon factory BL14A. The electric field of irradiated X-ray is vertical direction. Our PSPC rotates in the perpendicular plane to X-ray beam. The irradiated X-ray energy is 30-80keV.

References
[1] Shirasaki.Y et al., SPIE 4851 (2003) 1310.
[2] Mihara. T et al., SPIE 4497 (2002) 173.
[3] Tabata. T et al., NIM 103 (1972) 85.

3. Results

We obtained the photoelectron distribution and spectra as shown in Figure6. The photoelectron distribution was extracted from photoelectric absorption events except Compton scattering events. We could observe the different distribution at $P_{//}$ and $P_{\perp}$ position. This difference is caused by X-ray polarization. Our PSPC could detect the X-ray polarization with simple method. In addition, the electron range could be derived from 1dimentional distribution. We compared the measurement value and calculation value as shown in Figure7.

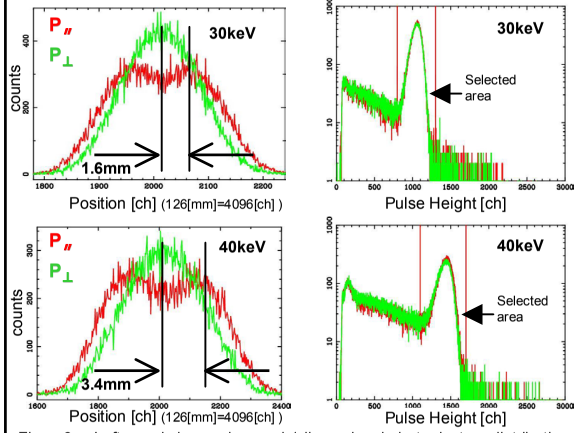


Figure6. Left panel shows observed 1dimensional photoelectron distribution at 30keV and 40keV. These figure were extracted from photoelectric absorption events. The region of extracted area are displayed above right panels.

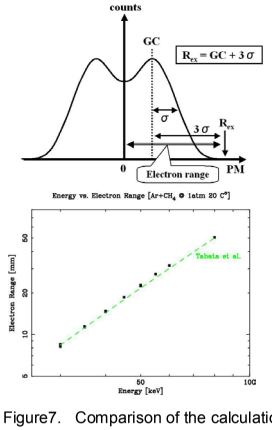


Figure7. Comparison of the calculation value(line) with our experimental data(marks).