Abstract

A gas Xe based scintillation proportional counter with cylindrical geometry and wavelength shifting (WLS) fiber readout for X-rays of energy $0.5 - 100\,\text{keV}$ is proposed. With such a design large sizes and sensitive area of the counter with a fairly well uniformity is possible. The counter could be used for "dark matter" search and neutrino magnetic moment measurement and for detection of small amounts or traces of radioactive elements in substances or environment.

Introduction

The electroluminescent (scintillation proportional) counters with a single anode wire and a PMT readout having a "pill-box" and cylinder geometry was investigated so far in the pioneer works of A. Policarpo [1,2,3]. It was shown that gas gain and electroluminescence take place simultaneously, and $100 - 1000$ times greater light yield with respect to that of $NaI(Tl)$ crystal viewed in the same light-collection conditions and excellent energy resolution of 11.2% for 5.9 keV X-rays were obtained. There are the following general advantages

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of scintillation proportional counters with respect to usual gas proportional counters.

- An energy resolution of such a counter is usually better than that of a gas proportional counter with charge collection because it operates at lower values of gas gain, and therefore, the last contributes smaller fluctuations.

- An equivalent electronic noise is $5 - 10$ times lower than that of a proportional counter with a typical preamplifier owing to the use of a PMT as a low-noise device. This fact is very important for application of the detector in a few-keV energy range.

- The value of HV potential is lower; thus, the breakdown problem is reduced, and a counter can operate at higher pressure, and therefore, possess higher detection efficiency for X-rays.

- The requirements on HV stability and wire uniformity is lower because the gas gain which is most sensitive to these parameters has lower value.

- The HV circuit is not electrically coupled with a spectrometric channel. This eliminates possible electrical breakdown in the circuit.

- There is no microphonic noise even for the counter of large sizes.

However, the counters of such a type are not widely used. The main reason is that the light-collection problem arisen for the cylindrical counter with a great value of the length-to-diameter ratio. One of the ways to solve this problem is described in [4]. Authors of this work used p-quaterphenyl as a wavelength shifter deposited on the inner wall of the cylinder coated with MgO diffusive reflector. The energy resolution of 6.4 % (FWHM) at 13.9 keV energy of X-rays was obtained with the counter having 5 cm diameter and 7.5 cm length (the length-to-diameter ratio is 1.5). However, for larger ratio such a method is inefficient.

**Method**

Better results for large length-to-diameter ratio are possible with a wavelength-shifting (WLS) optical fiber readout of the electroluminescent UV signal. The fibers to be located near the inner surface of the cylinder. They reemit the UV light and transport it through the glass window to the PMT placed outside the Xe volume. This method allows one to use both a PMT and window of a small diameter, and thus, to operate with Xe in a scintillation proportional mode at a pressure of several atmospheres. Moreover, large sizes of the
counter (a length of up to 1 m and a diameter of up to 10 − 20 cm) are possible without increasing PMT diameter. Optical fibers usually have small light attenuation, and residual light-collection nonuniformity can be avoided by simultaneous recording of the light from opposite ends of fibers. According to [5] the yield of 0.006 photoelectrons per one ultraviolet photon in pure Xe can be obtained with WLS fiber readout.

Device and experimental results

To check this approach we have built a prototype of the counter schematically shown in Fig. 1. The stainless steel tube with an inner diameter of 35 mm is filled with Xe under a pressure of up to 8 atm. Xe was purified before filling by passing through the "Oxisorb". A total length of the sensitive volume is \( \sim 20 \text{ cm} \). Eight cathode wires (0.07 mm in diameter) are located at a distance of \( \sim 1 \text{ cm} \) from the central anode wire (0.05 mm). The \(^{241}\text{Am}\) gamma-ray source is installed on the inner surface of the wall at a distance of \( \sim 5 \text{ cm} \) from the end of the sensitive volume.

Preliminary measurements of the pulse heights from the PMT coupled with a single fiber was carried out by means of UV light source (\( \lambda = 170 \text{ nm} \)) placed at various distances from the PMT (Fig. 2). A slope of the efficiency curve can be explained by self absorption of the fiber and possible nonuniform distribution of the wavelength shifter along the fiber. The value of an attenuation length obtained (\( L_{\text{att}} \sim 1 \text{ m} \)) is typical for the fiber used.

Fig. 3 shows the pulse height spectrum measured with \(^{241}\text{Am}\) gamma-ray source at a pressure of 2 atm (see figure capture for identification of the peaks). The photoelectron yield is about of 450 ph.e/keV, the energy resolution is 13.3 % (FWHM) at 13.9 keV.

The energy resolution of the prototype tested is worse than the superior values achieved with scintillation proportional counters. Optimization of geometry and values of gas gain and electroluminescent amplification is necessary to improve the energy resolution of the counter.

Conclusion

A WLS fiber readout for Xe gas scintillation proportional counter of cylindrical geometry is proposed. This method provides possibility to make relatively large and long counters which could be used for “dark matter” search and
neutrino magnetic moment measurement, where massive detectors with very low energy threshold are required. Also, it could be used for microdosimetry and monitoring of environment.

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References

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Figure caption

**Fig. 1** Schematic diagram of the prototype. 1 - fibers; 2 - cathode wires; 3 - anode wire; 4 - glass window; 5 - $^{241}$ Am.

**Fig. 2** Light collection efficiency of the fiber irradiated by 170-nm UV light versus distance from PMT.

**Fig. 3** Pulse height spectrums obtained with $^{241}$ Am source. $P = 2\text{ atm}$, $U_a = 2.9\text{kV} \sim 450\text{ph.e/keV}$: 1 - pedestal; 2 - $L_\alpha$ Np (13.9 keV); 3 - $L_\beta$ Np (17.8 keV); 4 - $K_\alpha$ Xe (29.8 keV), 59.6 keV – $K_\alpha$ Xe;
