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Test-beam aging studies of a TMAE prototype for the HERA-B RICH

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Abstract

The aging properties of a wire chamber, operating in a Methane/TMAE gas mixture, were studied in a beam test. We emphasize here the precautions taken to minimize aging due to materials used in the chamber, and the redundancy in the design of the test. We compare our aging results to those recorded in the literature and find good agreement in the overall aging properties as a function of dose. We also report the results of increasing the high voltage of the aged chamber to restore the gain.

Keywords: Aging, TMAE, HERA-B, RICH.

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1. Introduction

TMAE (tetrakis dimethylamino ethylene) is a photosensitive molecule with low ionization potential (5.3 eV). When TMAE is added in trace quantity to the operating gas of a wire chamber, the chamber becomes photosensitive. Such a technology has been used in Ring Imaging Cherenkov (RICH) detectors for the detection of Cherenkov photons for charged particle identification. The applications have been confined to experiments in which the expected dose is low because of the poor aging properties of TMAE chambers. The aging problem is especially severe in TMAE because the pulse height spectrum induced by single photoelectrons is an exponential function, and the efficiency depends sensitively on the threshold. The problem faced by such a technology in high radiation applications, such as in the HERA-B experiment [1], is the substantial loss of Cherenkov photon detection efficiency due to the reduction of the gain of the chamber. Aging studies of a TMAE chamber constructed with 25 micron anode wires showed that the aging rate is too fast for HERA-B conditions [2]. It has been shown that the aging rate can be slowed down by using thicker anode wires [3]. A beam test of a TMAE prototype chamber in an electron beam aimed at studying the aging properties of a chamber with 45 micron wires was conducted [4]. It was observed that the aging rate of the 45 micron wire diameter chamber is indeed slower, but the improvement is not sufficient for use in HERA-B. We also investigated the effect of raising the high voltage of the aged chamber to restore the gain. The aging cycle continues in the elevated operating high voltage, nullifying the improvement after several cycles. In this paper, we report on the details of the studies, especially those related to the choice of materials for the chamber. We compare our aging results to those in the literature.

2. Chamber construction

The construction of the chamber took into account the corrosive properties of TMAE. The prototype chamber was constructed with brass sheets which were slotted halfway and interleaved to form a chamber of 64 square cells, each 8mm x 8mm in area (see Fig.1). The 45 micron gold-plated tungsten anode wires were supported by a G-10 bridge in the entrance of the chamber and a G-10 backplane at the back of the chamber. The length of the cells was 10 cm, corresponding to about 2 absorption lengths for chamber gas 50% saturated with TMAE. Previous detectors were operated at near 100% saturation. The lower TMAE concentration prevented the condensation of TMAE on chamber surfaces, which has been known to accelerate the corrosive effect of TMAE and cause cathode aging. The chamber was housed in a stainless steel box, fitted with a quartz window. Materials used in the chamber were carefully chosen to avoid known aging problems. Among them, viton O-rings were used for the gas seal of the quartz window. The G-10 backplane was covered by DP-190, an epoxy tested to be resilient to TMAE. A complete stainless steel gas system was used. High purity methane (99.99%) was used as the chamber gas. Gas contaminants known to be bad for aging, mainly water and oxygen, were removed by an Oxisorb filter. The TMAE used was purified by bubbling nitrogen through until 5% of the TMAE was removed. This process allegedly removes TMAE radicals formed in the liquid, also thought to be bad for aging. Half of the methane was bubbled through TMAE liquid at room temperature so that the methane was nominally half-saturated with TMAE at room temperature.

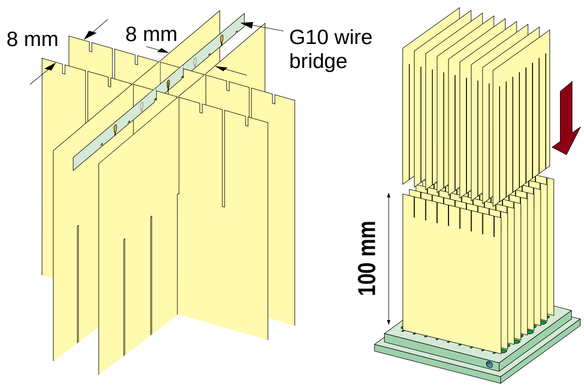

Figure 1. Schematic of the layout and construction of the TMAE test chamber.

3. Beam test setup

The beam test was conducted at the 3 GeV electron test beam at DESY. The prototype chamber assembly was housed on the upstream flange of a 5-m long cylindrical radiator tank (see Fig.2). The cylinder was filled with argon, the radiator gas. The radiator was equipped with a spherical mirror inside the tank at the downstream end so that the Cherenkov photons emitted by the electrons were focused on a ring intersecting the prototype chamber. The aging of the chamber was accelerated by photons from a deuterium lamp. The photon flux was controlled to simulate the expected rate at HERA-B, about 3 MHz/cm^2. The photon flux was measured by a UV PMT, behind a 210-nm filter, to monitor the aging of the lamp. The aging of the lamp was measured to be small for the test period and was corrected for in the analysis. In order to study the aging rate as a function of the irradiation dose, we covered the chamber with a mask with different-sized holes so that the 4 quadrants of cells were exposed to 4 different irradiation rates: 100%, 64%, 32%, and 0% of the maximum rate, respectively. The signals from the chamber were amplified and recorded by using an existing DAQ system. The pulse height spectra of the 16 cells, obtained by measuring the counting rate as a function of signal discriminator threshold, were taken once every half hour. Every 2 to 3 days, the deuterium lamp was turned off so that the Cherenkov photons could be measured. The efficiency for detecting the Cherenkov photons was measured as the number of chamber hits in coincidence with an electron trigger. During the test, the external parameters (temperature and pressure) were recorded.

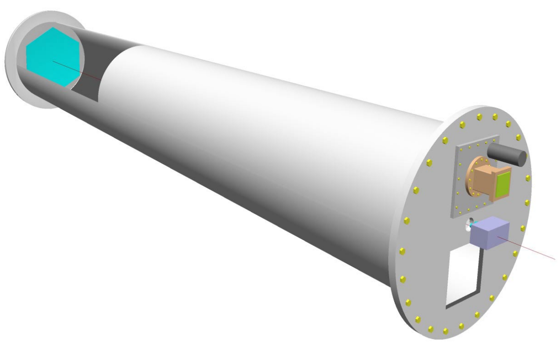

Figure 2. Drawing of the beam test setup showing the test chamber and the spherical mirror inside the radiator tank.

4. Results

4.1. Pulse Height spectrum

The pulse height spectra for Q4 (100% exposure) are shown in Figs. 3 and 4, where the counting rate of each cell is plotted against the threshold. The threshold is expressed in volts, with 70 mV = 1 fC. Since the single-electron pulse-height spectrum is exponential, the counting rate above some threshold is also an exponential function. The data for each cell were fitted to an exponential function, from which the gain of the cell and its counting rate at zero threshold were extracted. There are small differences in the gains among the 16 cells. The initial "gain" of cells was measured to be 0.138 V, corresponding to an absolute gain of about 4×10^5. The counting rate at zero threshold is about 2.5 MHz, in agreement with the expected photon flux (see Figure 3). The pulse height spectra for the same quadrant taken at later times after exposure to the UV light showed a dramatic decrease in gain. As Fig. 4 shows, the typical gain has dropped by almost a factor of 2 after only 2 days of exposure. It is also noticed that the counting rate at zero threshold has decreased somewhat, indicating efficiency loss due to other sources.

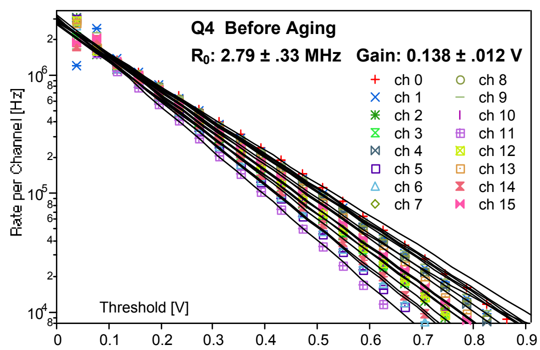

Figure 3. Pulse height spectra for Q4 cells (100% exposure) before aging.

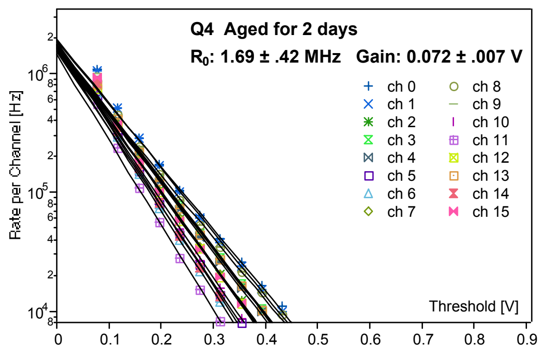

Figure 4. Pulse-height spectra for Q4 cells (100% exposure) after 2 days of aging.

4.2. Cherenkov detection efficiency

The counting rates for Cherenkov photons are shown in Figs. 5 and 6, where the size of the box is proportional to the number of counts per 10,000 triggers. Fig. 6 shows the performance after the chamber was exposed to radiation for 2 days. Again, we observed a decrease in counting rate as a function of dose, in conjunction with the decrease in chamber gain.

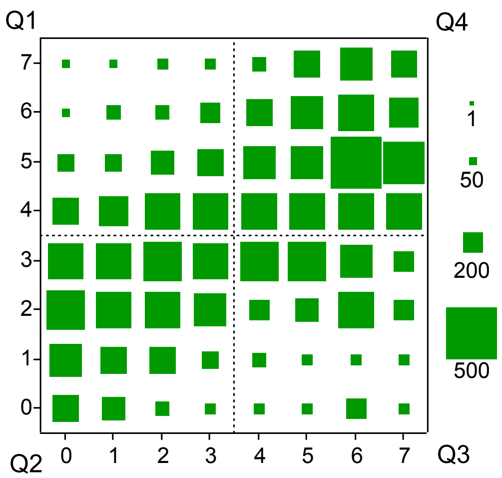

Figure 5. Number of hits per 10,000 triggers before aging.

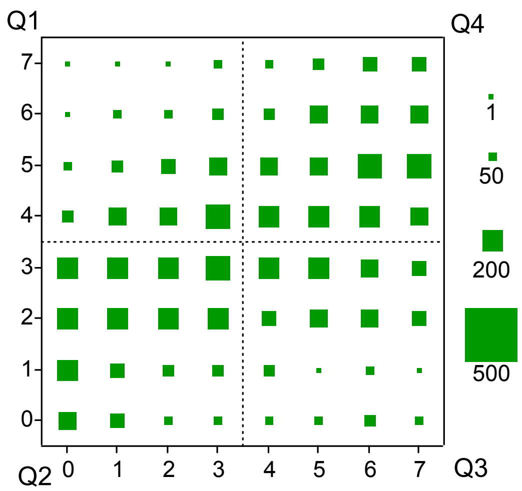

Figure 6. Number of hits per 10,000 triggers after aging for 2 days.

5. Summary of results

The aging results are summarized in Fig. 7, where both the gain and the Cherenkov light detection efficiency are plotted against the charge collected by the wire for two different quadrants, Q3 (0% exposure) and Q4 (100% exposure).

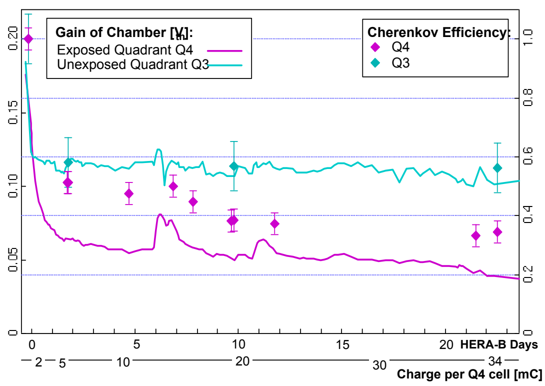

Figure 7. Summary of aging results. The solid curves depict the gains of Q4 and Q3, as a function of dose. The data points are the Cherenkov photon detection efficiencies (right scale) for Q4 and Q3, relative to their unaged values.

Both the gain and efficiency measurements corroborated a rapid initial drop, even before the chamber was exposed to radiation. Although quadrant 3, which was covered throughout the test, was exposed to very little radiation, both the gain and the efficiency of Q3 dropped to about 1/2 of their initial values. The other quadrants showed various levels of aging, with most aging associated with the highest exposure. The general trend was a slowdown in the aging rate to about 6%/mC/cm after the fast initial drop.

6. Remedy attempt by raising the high voltage

If the loss of gain were due to the increase in the wire diameter as a result of deposits on the wire, the gain could be recovered, in principle, by increasing the high voltage. Toward the end of the test, we attempted to recover the efficiency of the aged cells by increasing the operating high voltage of the chamber. We first raised the high voltage by 100 V, from 2650 to 2750 V. Indeed, in both the exposed and unexposed quadrants, the efficiency of the chamber increased by about 35% from its value just before the high voltage was increased. Fig. 8 plots the gains and Cherenkov photon detection efficiencies of Q3 and Q4 2 weeks before and 2 weeks after the increase of the high voltage, using the same scales and notations as those in Fig. 7. The chamber continued to age at the rate of about 10% per week

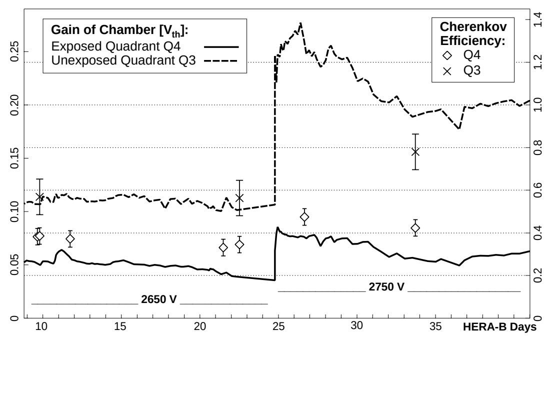

Figure 8. The gain and efficiency of the chamber 2 weeks before and 2 weeks after the first increase of the high voltage by 100 V. The scales and notations are the same as those of Fig. 7.

after the increase of the high voltage, which is about 3 times higher than the aging rate just before the increase. After 1 month of aging at 2750 V, we raised the high voltage by another 100 V. The chamber showed a similar increase in gain, but the chamber began to draw current.

The high voltage exercise suggested that the aged wire was probably not uniformly coated with deposits. There were probably more deposits in the front part of the wire where the light entered. The back part of the wire probably started arcing when the high voltage was raised. Some uncoated areas may have become corona points at the elevated high voltage.

It is also apparent that a new cycle of aging begins as the high voltage is increased, with a higher aging rate at the beginning. Similar behavior was observed when the aged wire was heated in situ in an attempt to recover the gain by evaporating the deposits [5]. The efficiency was comparable to that of a new chamber immediately after the heating, but the aging rate increased so that the same level of aging was reached in less time.

7. Comparison with other experiments

Table 1 compares the aging results of this experiment (row 1) with results from other experiments. The aging rates are calculated as a percentage decrease in gain per milliCoulomb (mC) of charge deposited on 1 cm of the wire, separately for the fast and slow components. Other pertinent data of the measurements, such as wire diameter and total exposure, are also listed. The aging rates of an otherwise identical chamber (see Fig. 9) except for the wire diameter (25 micron) are shown in the third row in Table 1. The behaviors of these two HERA-B TMAE prototypes are quite similar. There is a fast drop of gain of about 50-100%/mC/cm, followed by a slower drop of 6-20%/mC/cm in gain.

Table 1. Comparison of aging results of TMAE chambers.

Wire diameter	Carrier gas	TMAE concentration (% of saturation)	Fast aging rate (%/mC/cm)	Slow aging rate (%/mC/cm)	Approximate total dose of test (mC/cm)	Reference
45 micron	Methane	50%	100	6	8	[4]
33 micron	Methane	100%	50	6	2	[3]
25 micron	Methane	50%	50	20	1	[2]
15 micron	Ethane	100%	80	Not known	1	[6]

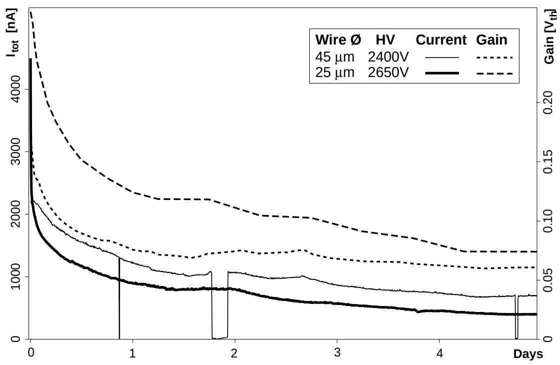

Figure 9. The currents and gains of the 25 and 45 micron HERA-B TMAE chambers as a function of exposure time to radiation.

The aging results of these HERA-B TMAE chambers are also quite similar to those obtained in a chamber with 33 micron carbon wires [3]. It is noteworthy that the study in [3] was conducted up to about 2 mC/cm, about a factor of 4 lower than this experiment. The aging results in Ref. [6] did not separate fast and slow components, so the aging is assumed to be entirely in the fast component. These results support the general conclusion that the aging rate is lower in chambers with larger-diameter wires.

8. Conclusions and discussion

Extensive aging studies of wire chambers filled with Methane/TMAE gas have been carried out by several groups. There is general agreement in the overall behavior. At the beginning, there is a fast drop in gain whose rate depends on the diameter of the anode wire and on other factors. This is followed by a slow decrease of gain which is smaller for thicker anode wire. There is a considerable drop of gain after a dose of about 1 mC/cm. This limits the use of TMAE chambers in hadron environments where an annual dose of 10-100 mC/cm is expected. Raising the high voltage of the aged chamber initially recovers the loss of gain, but aging continues at a higher rate.

Acknowledgements

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References

[1] T. Lohse, et al., DESY-PRC 94/02, 1994.
[2] P. Krizan, et al., Nucl. Instr. and Meth. A 387 (1997) 146.
[3] J. Vavra, SLAC-PUB-95-6759.
[4] J. Pyrlik, et al., Nucl. Instr. and Meth. A 414 (1998) 170.
[5] S. Skrk, et al., these proceedings.
[6] K. Martens, et al., Nucl. Instr. and Meth. A 343 (1994) 258.