Aging and Rejuvenation of a TMAE + Methane Multiwire Photon Detector

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Abstract

A UV sensitive multiwire photon detector has been tested as a possible candidate for the HERA-B RICH detector. The main obstacle to using such a TMAE+Methane filled gas detector in a high rate experiment appears to be rapid aging in the form of prohibitive loss of chamber gas gain. A special circuit has been designed for heating the anode wires in-situ with elevated currents, thus evaporating the polymer deposits. Heating almost completely recovers the initial gain, but this rejuvenation is unfortunately of short duration. Nevertheless, the cells exposed to periodic heat treatments have an average gain considerably higher than the non-heated cells.

I. Introduction

The HERA-B experiment [1] will measure CP violation in the B meson system using thin target strips in the halo of the 820 MeV/c proton beam in the HERA collider. The bunch crossing time of $96\,\mathrm{ns}$ and the $\sim$40 MHz interaction rate, necessary for detection of a few thousand of the chosen B decays per year, impose strict demands on the various detector components. The tagging of the flavour of the decaying B meson will be performed by a ring imaging Cherenkov (RICH) detector, which will identify the kaon into which the associated B meson decayed.

As one of the candidates for the RICH photon detector, a TMAE+methane filled gaseous multiwire detector, inspired by the JETSET chamber [2], was considered. A serious problem, however, could be the aging of the detector, which is manifested by the loss of chamber gas gain and thus of efficiency [3], [4]. The lower efficiency in turn reduces the number of detected photons per Cherenkov ring and thus the velocity resolution. In the present paper, we report on studies of aging and on the performance of a scheme for in-situ heating of the wires. The heating would possibly evaporate the deposits on the anode wires and hopefully recover the necessary gas gain.

II. Experimental apparatus

The test module (Fig. 1) consisted of 64 (8×8) cells with $8 \times 8\,\mathrm{mm}^2$ cross section and $10\,\mathrm{cm}$ length. It was made of $0.2\,\mathrm{mm}$ thick, slotted, gold-plated bronze plates [5]. A 50 μm diameter gold-plated tungsten anode wire was stretched along the axis of each cell, being soldered to an end plate on one end and to a ceramic bridge (Fig. 2) on the other. The module was closed by the end plate and by a quartz window on the bottom and on the top, respectively. Such a design ensured short drift times required by the 96 ns bunch crossing time in HERA. The $10\,\mathrm{cm}$ length of the cell permitted operation with a TMAE vapour pressure below saturation thus avoiding condensation while preserving high quantum efficiency. This was achieved by passing only a fraction ($\sim$40%) of the methane carrier gas through a TMAE bubbler at room temperature. Another advantage of such a chamber design is that the optical separation of different anode wires eliminates cross-talk due to photons created in the electron multiplication avalanche.

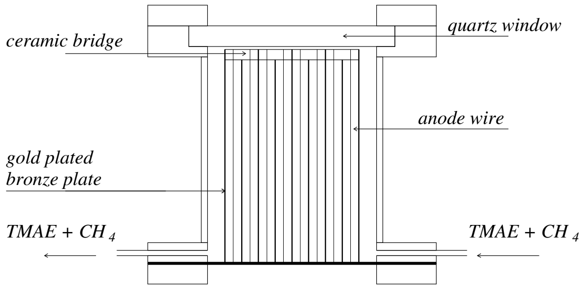

Figure 1: Schematic diagram of the experimental apparatus.

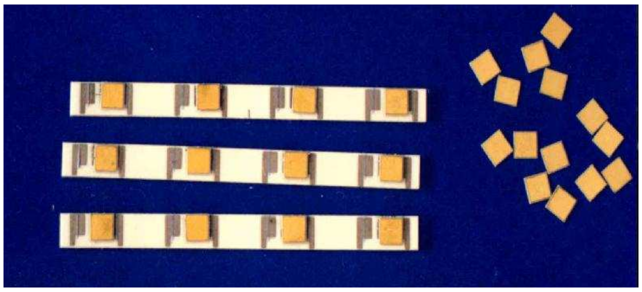

Figure 2: Ceramic bridges with diodes.

The signals were read out by charge sensitive preamplifiers [6]. They were then led through amplifiers (EG&G Mod.574) to CAMAC discriminators (Philips Mod.7106) and to CAMAC scalers (CAEN, Mod.C257) (Fig. 3). The anode current was monitored throughout the tests by a sensitive current meter (Keithley 617) allowing determination of the collected charge. The entire CAMAC system was controlled by a personal computer with the aid of the LabView programme package.

With -2650 V on the cathode plates and with the anode wires at ground potential, an exponential pulse height distribution, due to single photons, was obtained. As the discrimination thresholds could be set by the computer program, quick and frequent scans of the individual cell count rates versus threshold voltage could be performed.

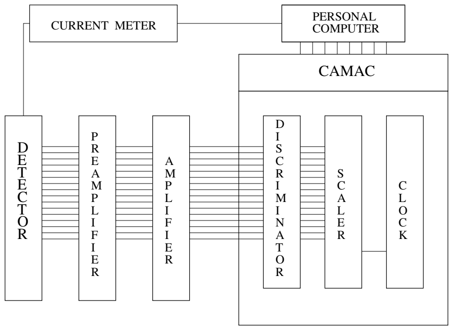

Figure 3: Block diagram of the readout electronics modules.

This distribution of count rate versus threshold voltage is exponential (Fig. 4), with the logarithmic derivative inversely proportional to the average pulse height. The count rate extrapolated to zero threshold gives the total number of photoelectrons created. Such a procedure allows almost continuous monitoring of the gain, of the quantum efficiency of individual cells or of the light source intensity.

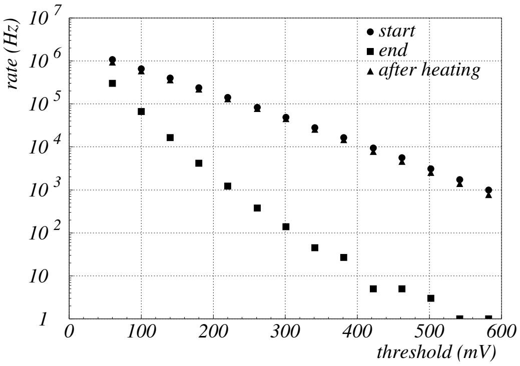

Figure 4: Dependence of the count rate on threshold voltage (for one cell) at the beginning of illumination (circles), at the end of illumination (squares) and after heating (triangles).

III. Measurements and results

The detector was illuminated by a parallel beam of UV photons obtained by shining the light of a UV lamp through a pinhole in the focal plane of a spherical mirror (Fig. 5). Of the 16 cells equipped with readout channels only 8 were illuminated. The light intensity corresponded to an event rate of about 2.5 MHz per cell. Each group of 8 cells was further divided into two subgroups of 4 cells each, with one subgroup subject to heat treatment and the other not.

The effect of illumination, i.e. of aging, can be seen from the threshold scans. Fig. 4 for example, shows the threshold scans of one cell at the beginning and towards the end of illumination. The increase of the absolute value of the slope indicates that the chamber gain has dropped. The value of the rate, extrapolated to zero threshold, has however remained unchanged, consistent with no change in quantum efficiency and/or light intensity.

Mass spectrometry has been performed of the products evaporated from an aged anode wire (Fig. 6). The measurements showed no new products above a temperature of

Figure 5: The chamber was illuminated indirectly by shining light of the UV lamp onto the spherical mirror.

200^{o}C. This is fortunate since solder bonds could loosen at higher temperatures.

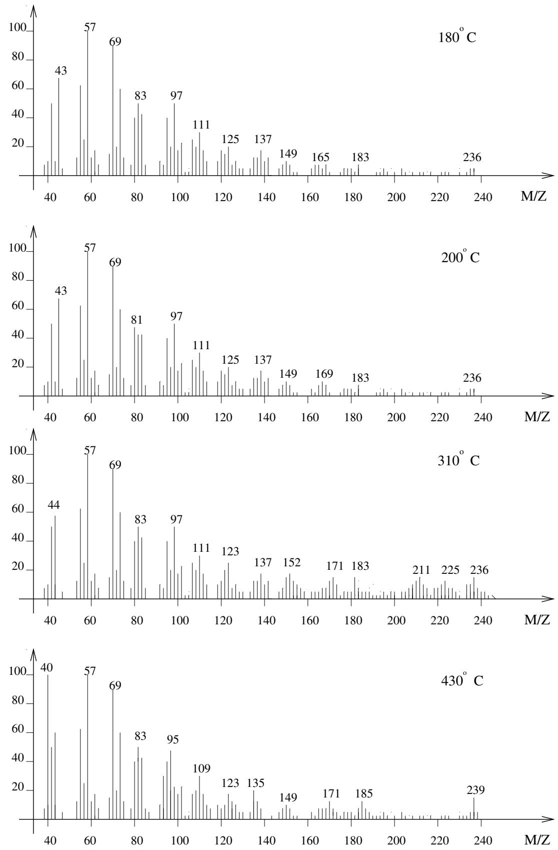

Figure 6: Relative abundances of products evaporated from an aged anode wire at T=180^{o}C, T=200^{o}C, T=310^{o}C and T=430^{o}C depending on their atomic masses, as obtained by mass spectrometry.

The anode wires have then been heated in-situ to 200^{o}C with a current of 0.29 A and a potential difference of 3.3 V across the wire (Fig. 7). The temperature has been estimated from the change in wire resistance and from the values of the temperature coefficient of resistance given by the manufacturer [7]. During heating, which lasted for about 1 hour, the chamber was flushed with pure methane, because such a procedure required no special intervention in the existing gas system.

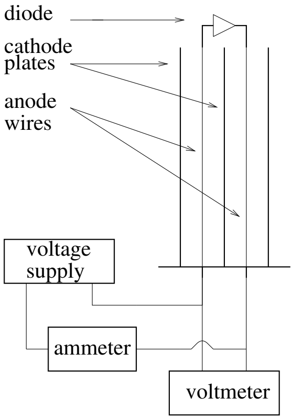

Figure 7: Schematic diagram illustrating the setup used to perform in-situ anode wire heating.

The beneficial effect of heating is evident from the result presented in Fig. 4. It is seen, that the chamber gain has almost completely returned to its value prior to illumination. Unfortunately, this recovery is not of very long duration as will be shown below.

The ratios of average pulse heights between different subgroups of 4 cells are shown in Fig. 8, Fig. 9, Fig. 10 and Fig. 11. Fig.reffig7 gives the time dependence of the ratio of average responses of illuminated to non-illuminated cells which have not been heat treated. It is obvious that after 300 hours of illumination the gain has fallen to about 30% of its value for non-illuminated cells. Heating of non-illuminated cells does not affect the gain, as may be seen from Fig. 9, where the ratio of average pulse heights of heated to non-heated cells that have not been exposed to light is shown to be constant in time. Fig. 10 shows the ratio of average pulse heights of illuminated to non-illuminated cells which have all been heated. The sharp peaks, where this ratio almost reaches 1, correspond to the short heating periods. The first 15- minute heat treatment at t=70 h was obviously insufficient, so the subsequent heating times were prolonged to 1 hour. The immediate increase in gain, achieved with heating, is unfortunately not very long lived as can be seen in Fig. 10. However, the overall effect of several short heat treatments is an average increase in gain, as evidenced by Fig. 11. This figure shows the ratio of average responses of heated to non-heated cells, all subject to illumination.

The measured anode wire current should be proportional to the product of the average pulse height and the count rate extrapolated to zero threshold. A constant ratio of this product to the current follows from our data, which means that the current and the rate measurements are consistent with each

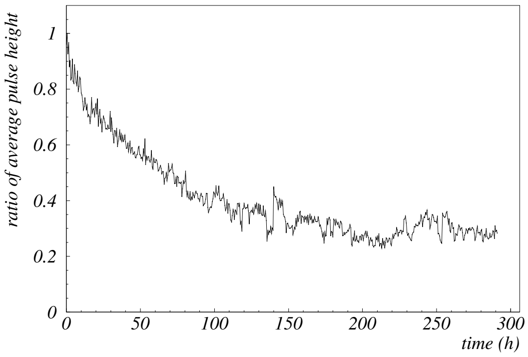

Figure 8: Time dependence of the ratio of average pulse heights between illuminated to non-illuminated cells which have not been heated.

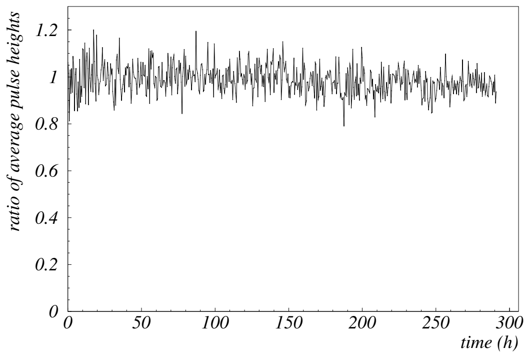

Figure 9: Time dependence of the ratio of average pulse heights between heated to non-heated cells which have not been illuminated.

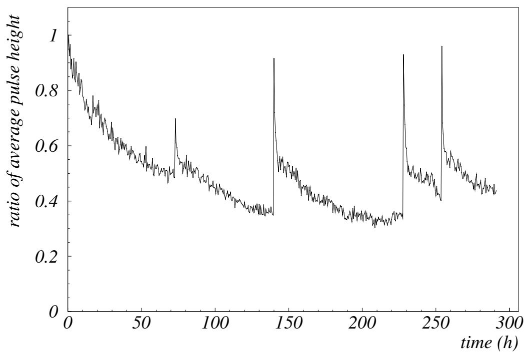

Figure 10: Time dependence of the ratio of average pulse heights between illuminated to non-illuminated cells which have been heated.

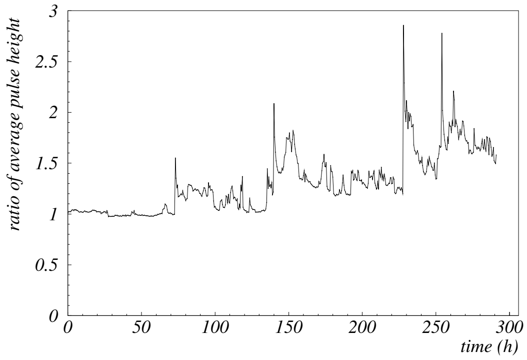

Figure 11: Time dependence of the ratio of average pulse heights between heated to non-heated cells which have been illuminated.

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other. A collected charge of 55 mC per cm^2 of detector surface has been deduced for the 300 hour duration of illumination. From the collected charge, from the effective wire length of 9 cm (1 cm is dead space) and from the relative loss of gain given by our data, one obtains an estimate of the aging factor. This factor is defined as the relative loss of gain per unit of deposited charge per unit of anode wire length. We obtained the aging factor of 420 cm/C for 50 μm diameter gold-plated tungsten wires at collected charge of 1.2 mC/cm and a gain loss of factor 2. At the same value of the collected charge our result can be compared with that of Va'vra. He obtained a gain loss of 30 % [3] and 70 % [8] for a 33 μm diameter carbon wire.

IV. Conclusions

Measurements performed with a test module of a TMAE+methane filled multiwire photon detector show aging in the form of loss of gas gain due to deposits on the anode wires. A special circuit designed for heating the anode wires in-situ with elevated currents, was used to evaporate these deposits. An almost complete recovery of the gain was achieved. Unfortunately this recovery is not of long duration, but is followed by a quick drop in gain. With periodic short heat treatments, an average gain considerably higher than for the non-heated wires could be achieved. Although this rejuvenation of the aged wires does not seem to be sufficient for HERA-B, it could hopefully be useful in experiments with somewhat lower rates.

V. Acknowledgements

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VI. References

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