Nuclear Instruments and Methods in Physics Research A 371 (1996) 151–154

ELSEVIER

NUCLEAR
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Section A

Tests of a large area MWPC with a CsI photocathode

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Abstract

The relative quantum efficiency of several CsI photocathodes in an asymmetric multiwire proportional chamber has been measured. The photocathode surface of $24 \times 24\,\mathrm{cm}^2$ is divided into $7.5 \times 7.5\,\mathrm{mm}^2$ pads and the chamber is operated with methane at normal temperature and pressure and a gas gain of about 10^5. During tests of the high rate performance ($\sim 2\,\mathrm{MHz/cm}^2$) of a smaller chamber ($5 \times 5\,\mathrm{cm}^2$), an interesting time variation of the count rate has been observed when illuminating the chamber with constant UV light.

1. Introduction

Reflective CsI photocathodes, with electron extraction into the methane gas in a multiwire proportional chamber, have been the subject of renewed interest and much research effort ever since the measurements of Seguinot et al. [1] resulted in high quantum efficiency values. Such CsI-MWPCs are position-sensitive detectors of individual photons with good timing properties and no parallax. They are attractive alternatives to MWPCs that use low ionization potential vapours (TMAE or TEA) for detection of Cherenkov rings. This is especially the case in experiments at the future high luminosity machines [2]. It seems however, not to be a trivial exercise to produce and maintain the CsI photocathodes with high quantum efficiency values. The present paper describes tests made with several $24 \times 24\,\mathrm{cm}^2$ CsI photocathodes, divided into $7.5 \times 7.5\,\mathrm{mm}^2$ pads for position-sensitive detection of the photoelectrons in a multiwire proportional chamber filled with NTP methane gas. Also presented are the results of high rate tests, performed with a smaller ($5 \times 5\,\mathrm{cm}^2$) MWPC.

2. Experimental apparatus

The photocathode has been produced by vacuum evaporation of CsI crystals onto a specially prepared printed circuit board (PCB). The central $24 \times 24\,\mathrm{cm}^2$ copper layer of the PCB has been divided into $7.5 \times 7.5\,\mathrm{mm}^2$ pads, which are by galvanization covered with a Sn/Pb layer. Before depositing the CsI, the Sn/Pb surface has been polished (1 μm polishing paste) and cleaned with detergent and water and thoroughly dried. The thickness of the CsI layers was typically between 500 and 1000 nm and was deposited at a rate of about 10 nm/s. Clearly visible interference rings permitted an estimate of the variation of the CsI thickness from the center outwards.

The anode wire plane, at a distance of 0.66 mm from the CsI photocathode, consisted of 10 μm diameter gold-plated

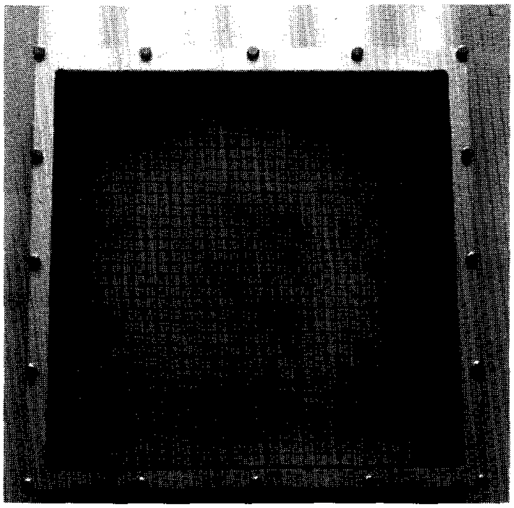

Fig. 1. The $24 \times 24\,\mathrm{cm}^2$ CsI photocathode with $7.5 \times 7.5\,\mathrm{mm}^2$ pads.

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SSDI 0168-9002(95)01149-8

tungsten wires at 2.5 mm pitch. The cathode wire plane, 1.5 mm above the anode plane, was made of 50 μm diameter Cu–Be wires at 1.25 mm pitch and oriented parallel to the anode wires. The chamber was closed with a 5 mm thick quartz window and flushed with 5 liters/hr of methane gas at normal temperature and pressure (NTP). With the photocathode at ground potential, the optimal voltages were found to be +1650 V on the anodes and −560 V on the cathode wire plane.

Signals induced on the pads, passed through conductive holes to preamplifiers on the opposite side of the PCBs. The soldered contact closed the holes and ensured gas tightness. The charge-sensitive preamplifiers were designed specially for the CsI pad readout [3], with 8.3 mV/fC conversion gain, 18 ns rise time, 24 ns fall time, 1000 electrons equivalent noise charge and 40 dB common mode RF suppression. The signals were further processed by the ARGUS μVDC readout system [4] and stored in a computer for off-line analysis.

The detector was tested with Cherenkov photons emitted by 3 GeV/c electrons in a 5 m long argon gas radiator. These measurements were performed with the T24 test beam at DESY in Hamburg and are described in the papers by Križan et al. [5–7]. These tests gave results that were in agreement with estimates of angular resolution and of timing resolution (Fig. 2). The number of detected Cherenkov photons per ring in these tests was, however, less than expected.

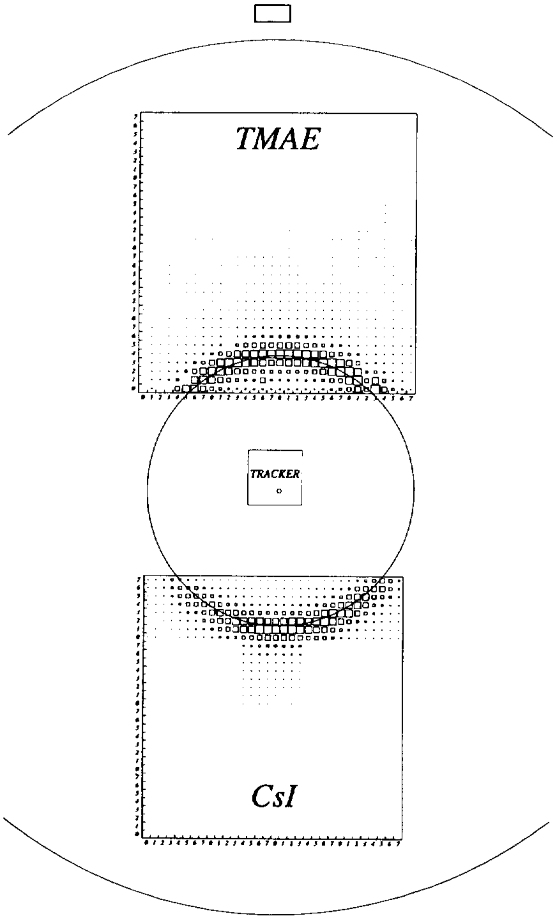

Fig. 2. The test-beam data showing parts of accumulated Cherenkov rings as seen by the CsI and the TMAE photon detectors [5].

3. Measurements and results

Possible reasons for this discrepancy could be attributed to a reduced UV transparency of the gas radiator, to the reflectivity of the mirror or to the CsI quantum efficiency. In order to find and eliminate the cause for this reduction in performance, a special apparatus was constructed (Fig. 3), with which the quantum efficiency could be measured with a ^{90}Sr source. β-particles from the source first pass through a small and thin (~8 mg/cm^2) trigger MWPC. They than enter the quartz radiator, where they produce Cherenkov photons, which are refracted out of the radiator and absorbed by the CsI photocathode through the photoelectric effect. The fraction of β-decays, leading to a detected photoelectron signal in the CsI-MWPC photon detector, depends among other parameters also on the photocathode quantum efficiency. Comparison of the measured relative rate of CsI-MWPC signals to the simulated relative number of detected Cherenkov events, gives a value for the quantum efficiency. In our case, this is the RQE factor for the photocathode under investigation [8] or the average ratio of its quantum efficiency to the standard quantum efficiency given by Seguinot et al. [1].

Due to lack of readout channels, 4 × 4 pads were connected to one channel. The single photoelectron detection efficiency was measured to be 80%. The results for the quantum efficiency of seven photocathodes measured

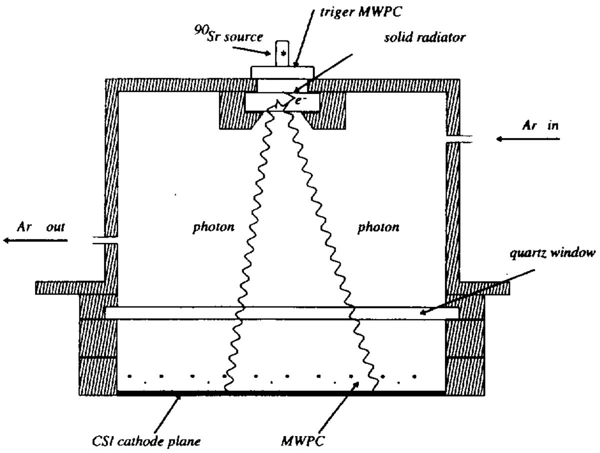

Fig. 3. The apparatus for on-the-bench tests of the quantum efficiency of 24 × 24 cm^2 CsI photocathodes with a ^{90}Sr source.

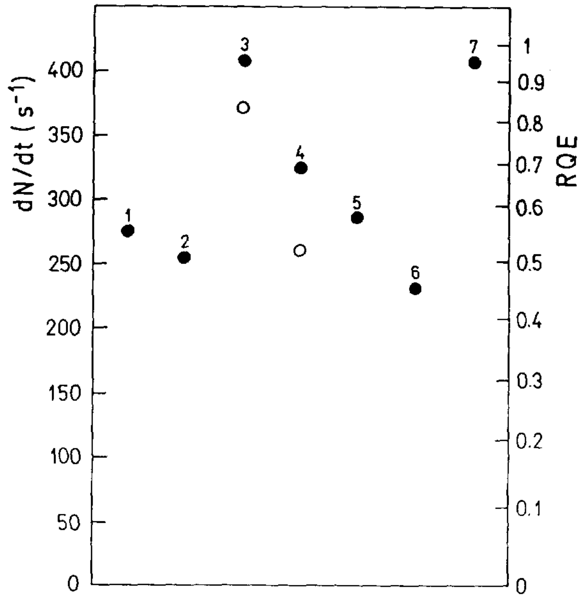

Fig. 4. The measured counting rates and corresponding relative quantum efficiency RQE for seven of the $24 \times 24\,\mathrm{cm}^2$ CsI photocathodes. Photocathodes no. 3 and no. 4 have been measured before (full circles) and after (empty circles) transport to Hamburg.

under these conditions are given in Fig. 4. Photocathodes number 3 and number 4 have been transported from Ljubljana to Hamburg and back to Ljubljana. It is seen that the transport and handling procedure, including intermediate exposures to air, reduce the RQE factor for only 0.15–0.20. The initial values of the quantum efficiency however, are scattered between 50 and 100% of the values obtained by Seguinot et al. [1]. The reason for this broad distribution of quantum efficiencies is not yet understood and is being investigated.

Some interesting phenomena have been noticed while attempting to study the high rate behaviour of a symmetric $5 \times 5\,\mathrm{cm}^2$ MWPC with $1\,\mathrm{cm}^2$ pads. An additional grounded wire plane was placed above the cathode wires and the anode wires were connected to 2 kV through a $10\,\mathrm{M\Omega}$ resistor. Initially the pads were just the Sn/Pb substrate without the photosensitive CsI layer, so the chamber was exposed to β-particles from a 1 mCi ^{90}Sr source. The source triggered a rise of current from 1 μA to about 30 μA. Due to the voltage drop on the resistor, this increase of current corresponds to a decrease of effective voltage on the anode wires. Some features of this elevated current are:

- the current jump is delayed with respect to the beginning of irradiation that triggers the jump,
- the high current persists even after the radiation source is removed,
- it can be seen in the dark even with the naked eye as glowing of the gas at points of high electric field (closest approach of anode and cathode wires),
- lowering of the effective anode voltage produces a decrease in the current as shown in Fig. 5.

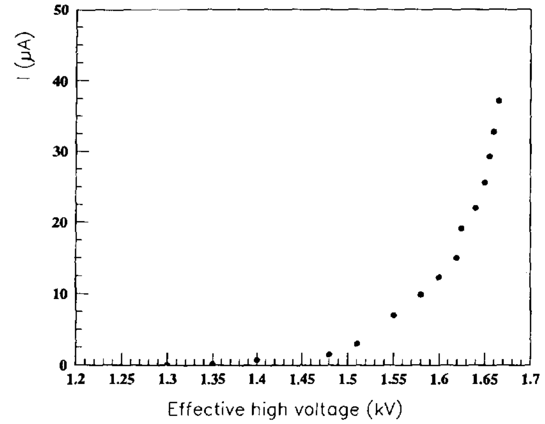

Fig. 5. The dependence of the current through the MWPC on the effective anode voltage in the absence of an ionization source (see text). A 1 mCi ^{90}Sr source is used just to trigger the high current.

The transition from low to high current is not simultaneous with the beginning of irradiation or illumination of the chamber, but occurs with some delay. It has been observed that this delay could be increased if positive voltage is applied to the cathode wire plane. With the pads covered by a CsI layer and illuminated with UV light, the delay has been measured as a function of positive voltage on the cathode wires for anode wire diameter of 10 and 20 μm (Fig. 6). For these measurements the counting rate has been kept at a constant value of 100 kHz, by slightly adjusting the anode voltage.

An interesting variation of the counting rate is seen in Fig. 7. Although the illumination is kept constant up to $t_1 = 6000\,\mathrm{s}$, the counting rate decreases from 2.4 to $2.0\,\mathrm{MHz/cm}^2$, where it stabilizes. At time t_1 the UV

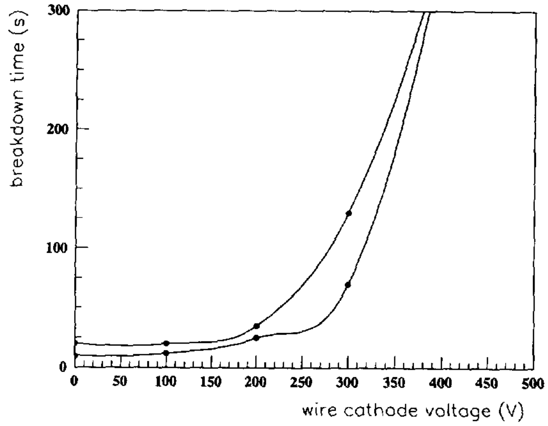

Fig. 6. The time delay between the beginning of illumination and the appearance of the large current as a function of the positive cathode wire voltage. Results are shown for anode wire diameter of 10 μm (upper curve) and 20 μm (lower curve).

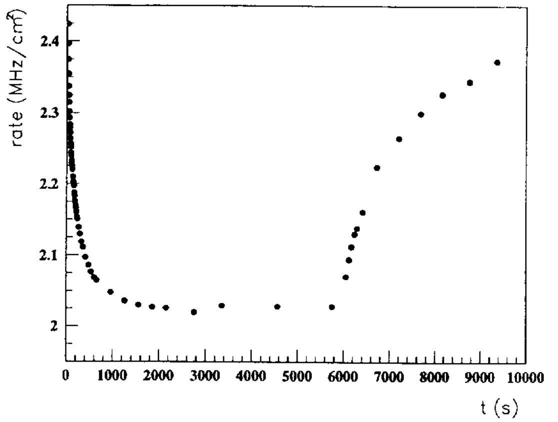

Fig. 7. The time variation of the counting rate with constant illumination of the chamber. At $t_1 = 6000$ s the illumination is blocked off with a plastic foil, which is removed only for short count rate measurements.

illumination is blocked off with a plastic foil, which is removed only for occasional quick rate measurements. The measured rates then increase with a time constant of the order of 1 hr.

The effects described above have been observed also in the case where the photocathode was without the photosensitive CsI layer. Thus it seems possible that these current and rate variations are due to surface charge accumulating on the cathode wires rather than on the CsI photocathode. Further investigations will hopefully shed more light on this problem.

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