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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

Tests of photon detectors for the HERA-B RICH

P. Križan[a,b,*], S. Korpar[d], M. Starič[a], A. Stanovnik[a,c], M. Cindro[a], D. Škrk[a], M. Zavrtanik[a], E. Michel[e], P. Weyers[e], W. Schmidt-Parzefall[f], T. Hamacher[g]

[a] *J. Stefan Institute, University of Ljubljana, P.O. Box 100, Ljubljana, Slovenia*
[b] *Faculty of Natural Sciences and Technology, University of Ljubljana, Slovenia*
[c] *Faculty of Electrical Engineering and Computer Sciences, University of Ljubljana, Slovenia*
[d] *Technical Faculty, University of Maribor, Slovenia*
[e] *DESY, Hamburg, Germany*
[f] *University of Hamburg, Germany*
[g] *University of Texas, Austin, USA*

Abstract

A multiwire proportional chamber with CsI photocathode pads and a TMAE based photon detector have been tested in order to evaluate their potential as candidates for a fast ring imaging Cherenkov counter, to be used for separation of pions from kaons in the HERA-B experiment proposed at DESY. Results of the tests are presented.

1. Introduction

The HERA-B experiment, proposed at DESY [1], is planned to measure CP violation in the B meson system. The tagging of B meson flavour through the kaon charge requires good π/K separation up to about 60 GeV/*c*. This task will be performed by a Ring Imaging Cherenkov (RICH) detector (Fig. 1) consisting essentially of a 2.7 m long C_4F_{10} gas radiator, a UV mirror and about 10 m^2 of position sensitive photon detectors.

The present paper describes tests of two different types of photon detectors in order to evaluate their advantages and disadvantages for the detection of Cherenkov photons in HERA-B. The first detector uses a TMAE–methane gas mixture in $8 \times 8 \times 100\,mm^3$ proportional counter unit cells, while the second type relies on a reflective CsI photocathode divided into $7.5 \times 7.5\,mm^2$ pixels in an asymmetric MWPC configuration.

Besides having high quantum efficiency and good position resolution, the detectors are required to be fast (96 ns bunch crossing time) and they should tolerate high rates (one bunch crossing generates 5 events with 200 particles of which 100 radiate Cherenkov photons) for longer periods of time without substantial decrease in performance.

2. Experimental set-up

In order to approach the environment of the real experiment, these tests were performed with the 3 GeV/*c* electron test beam T24 at DESY. An 80 cm diameter, 5 m long aluminium tank (Fig. 2) was filled with argon, which was used as radiator in these tests mainly because of its lower cost and simplicity of handling compared to C_4F_{10}. The beam electron trajectory was measured with two MWPCs on the entrance and exit flange of the gas tank. Cherenkov photons radiated by the beam electron were reflected from the mirror on the inside of the exit flange back to the focal plane at the entrance flange, where both photon detectors were situated. The TMAE and the CsI photon detectors were placed one above, the other below the beam tracking chamber, so each one detected part of the Cherenkov ring. A scintillation counter in front of the beam entrance MWPC was used for timing.

The TMAE detector consists of 32×32 unit cells of $8 \times 8\,mm^2$ cross section and 100 mm depth in order to reach sufficient photon absorption at room temperature. The cells are separated by gold-coated bronze walls. A 25 μm diameter anode wire is stretched along the cell axis through the end-plane on one side and a bridge on the other. The photon entrance window is made of 5 mm thick quartz. The chamber gas is methane of which a chosen fraction (40% in this case) is passed through a room temperature TMAE bubbler.

The $24 \times 24\,cm^2$ CsI detector is essentially an asymmetric MWPC with a reflective, ~1 μm thick CsI photo-

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[*] Corresponding author. E-mail peter.krizan@ijs.si

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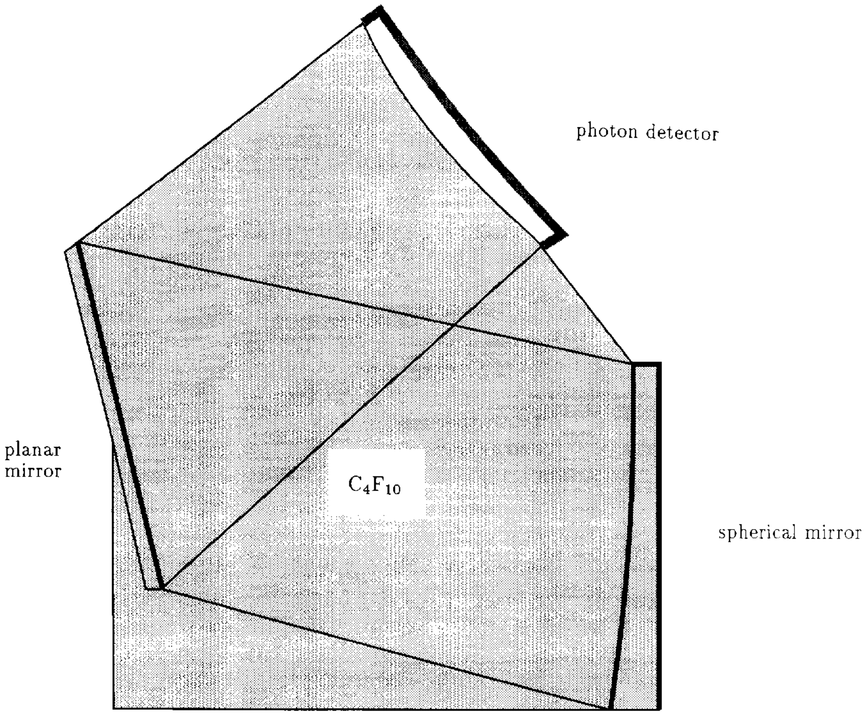

Fig. 1. Geometry of the HERA-B ring imaging Cherenkov detector.

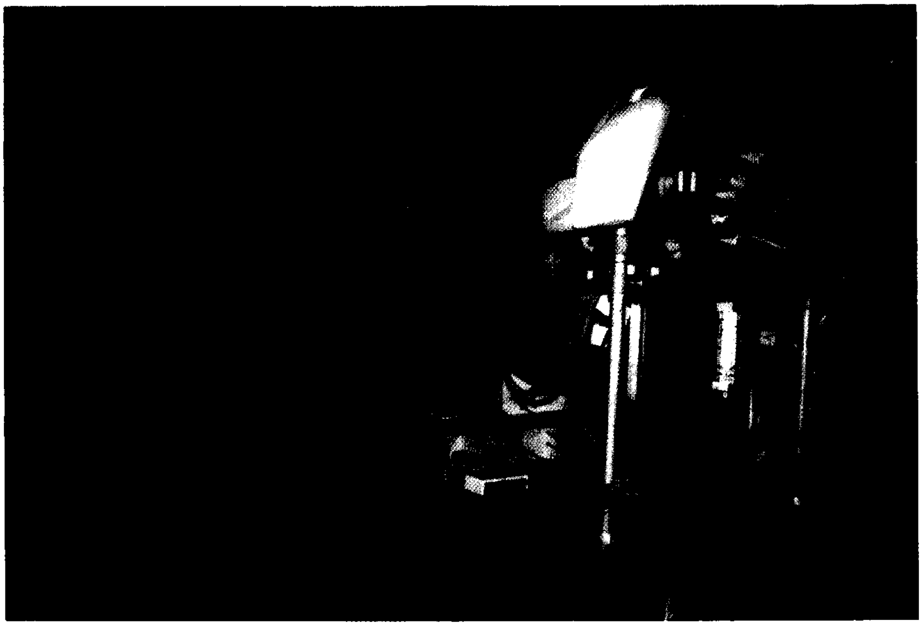

Fig. 2. Photograph of the test apparatus.

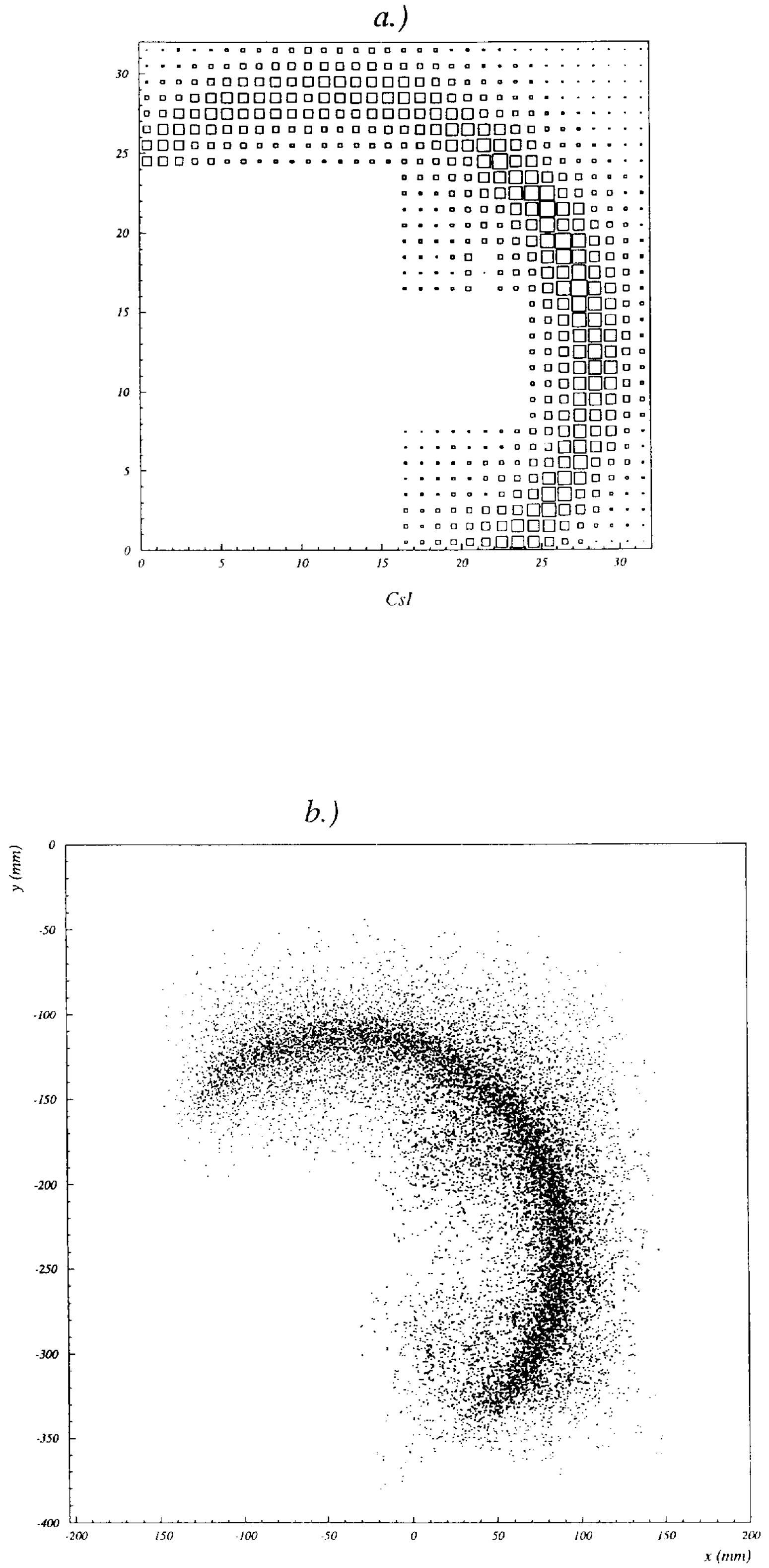

Fig. 3. The distribution of hits in the CsI detector: (a) raw data and (b) data corrected for beam particle divergence.

cathode, divided into $7.5 \times 7.5\,\mathrm{mm}^2$ pixels. The anode plane, with 2.5 mm wire pitch, is closer to the photocathode ($d_{pc} = 0.66$ mm) than to the wire cathode plane ($d_{wc} = 1.44$ mm and 1.25 mm wire pitch), which allows higher signals to be obtained from the photocathode pads. At the optimised voltages ($U_a = +1650$ V, $U_c = -560$ V) a gas gain of 10^5 in pure methane is obtained without problems. With specially designed, low-noise preamplifiers [2], a photoelectron detection efficiency of 90% could be reached. The ARGUS μVDC readout system [3] was used for both detectors.

3. Measurements and results

Fig. 3 shows the accumulated raw data and the distribution of hits after the correction for beam electron divergence. These measurements were made by tilting the mirror, so that most of the Cherenkov ring is intercepted by the CsI chamber.

In the symmetric position of the mirror, where both detectors would intercept equal numbers of Cherenkov photons, the average number of photoelectrons per event detected by the TMAE chamber was 3.2, and for the CsI chamber the number was 2.0. Assuming that the entire Cherenkov ring would be covered by one detector, these numbers would normalise to 10.2 and 6.2 for the TMAE and the CsI detectors respectively. Estimates based on expected values of the quantum efficiencies [4,5], photoelectron detection efficiencies, argon transmission [5] and mirror reflectivity data [6], yield approximately equal values for the number of detected photoelectrons in both detectors. Additional tests with Cherenkov photons emitted by β-particles from ^{90}Sr and the comparison with Monte Carlo calculations showed that indeed the CsI quantum efficiency was reduced on average to about 60% of the expected value. The relative quantum efficiency of individual pixels is indicated in Fig. 4, where the number of pixels depending on their relative quantum efficiency (RQE) is also shown. This problem could be caused by lengthy storage and transportation in the photocathode or could be a consequence of some differences in the production of larger photocathode surfaces as compared to previously measured smaller ones ($5 \times 5\,\mathrm{cm}^2$) [7]. Besides the lower CsI quantum efficiency, there seems to be another common factor of two discrepancy between the estimated and the measured number of photoelectrons for both detectors. This could be due to a reduced mirror reflectivity or gas transmission. Both problems are being investigated further.

The measured angular resolution derived from single photoelectron hits is about equal for both detectors and is in agreement with expectations. By correcting the beam electron divergence, the measured single-hit resolution is 0.85 mrad rms, which agrees with estimates based on multiple Coulomb scattering, MWPC position resolution etc.

The time spread of signals in methane has been measured to be 65 ns and 25 ns for the TMAE and the CsI detectors respectively. The measured distribution of drift time for ethane and methane gas in the TMAE detector is shown in Fig. 5.

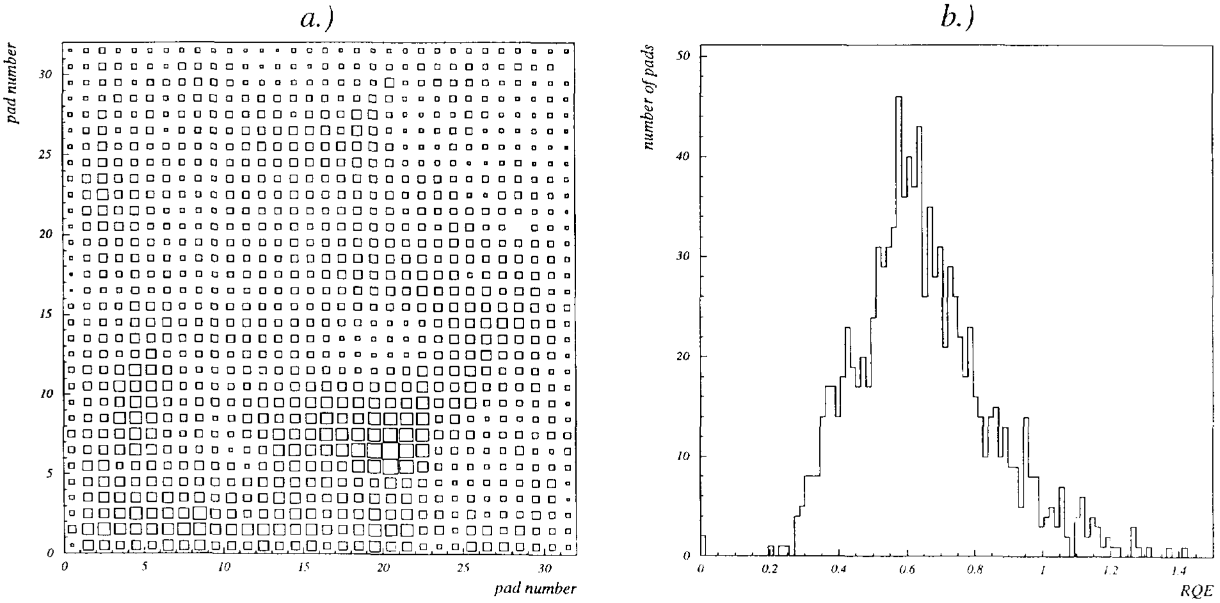

Fig. 4. The relative quantum efficiency of individual CsI pixels of one of the tested photocathodes (a). The distribution of pixels depending on their relative quantum efficiency (b).

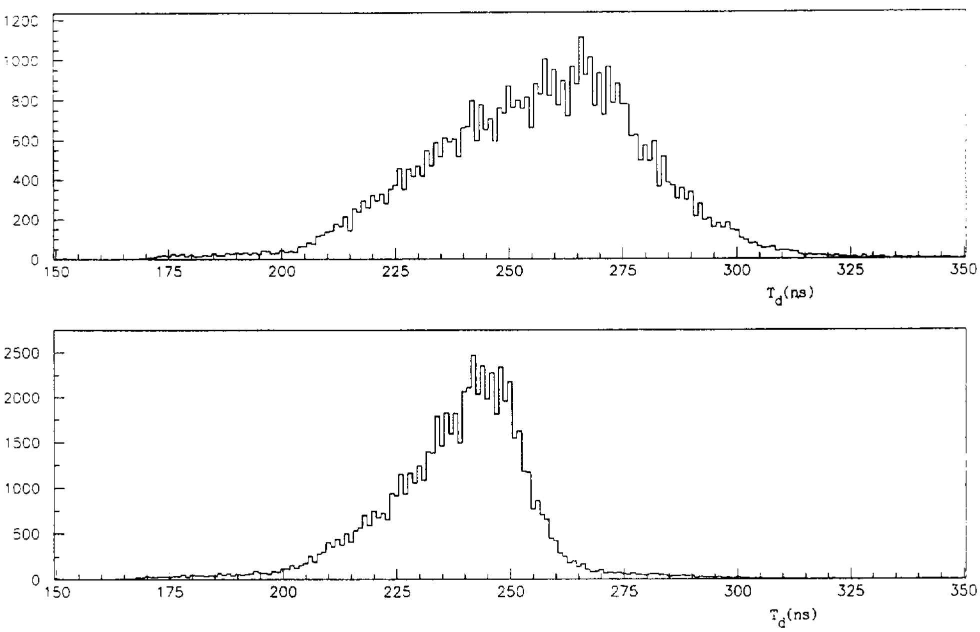

Fig. 5. Distribution of drift time in ethane (a) and methane (b) for the TMAE detector.

The reduction of the quantum efficiency at high densities of accumulated charge has been measured for the CsI detector (Fig. 6) [7]. Initially there is a fast decrease, then a short plateau followed by a decrease with the slope becoming smaller, so it seems that the quantum efficiency could be approaching a steady value of about half the initial quantum efficiency.

Another interesting result has been obtained by comparing the relative quantum efficiency (RQE) of individual pixels of the CsI detector before and after two months of storage (Fig. 7). The correlation would suggest that initially low RQE values decrease more than the higher initial values.

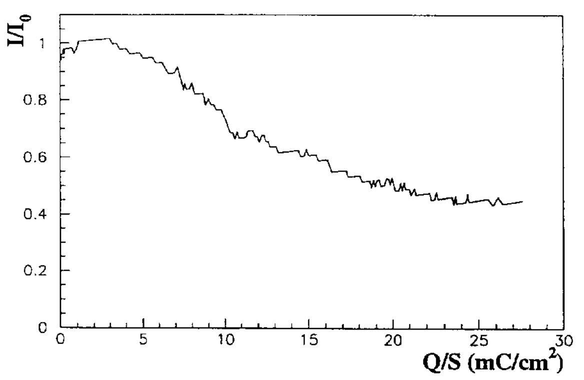

Fig. 6. The current through the CsI detector at constant illumination depending on the accumulated charge [7].

4. Conclusions

Comparative tests of a TMAE and a CsI photon detector showed that:

- both detectors have equal resolution of the Cherenkov angle derived from single photoelectrons and that this resolution is as expected from multiple Coulomb scattering, pixel size etc.
- both detectors detected less than the expected number of photoelectrons with the reduction being greater for CsI (~×3) than for TMAE (~×2).
- the time spread of signals is smaller for the CsI detector (25 ns) than for the TMAE detector (65 ns).
- ageing of CsI at larger surface densities of accumulated charge cold contribute a factor of two reduction in quantum efficiency.

The kaon identification efficiency depending on the average number of photoelectrons detected per kaon (Fig. 8) is a slowly rising function above 20 detected photoelectrons [1]. In 2.7 m of C_4F_{10}, with rather optimistic assumptions for the values of the relevant parameters (quantum efficiency, transmission, reflectivity etc.), estimates are that about 40 photoelectrons should be detected by either the TMAE or the CsI detector. Despite the comfortable difference between this estimate and the still acceptable value of 20 photoelectrons, it seems that further investigations will be necessary before one may be confident that the required performance will be achieved on a larger scale.

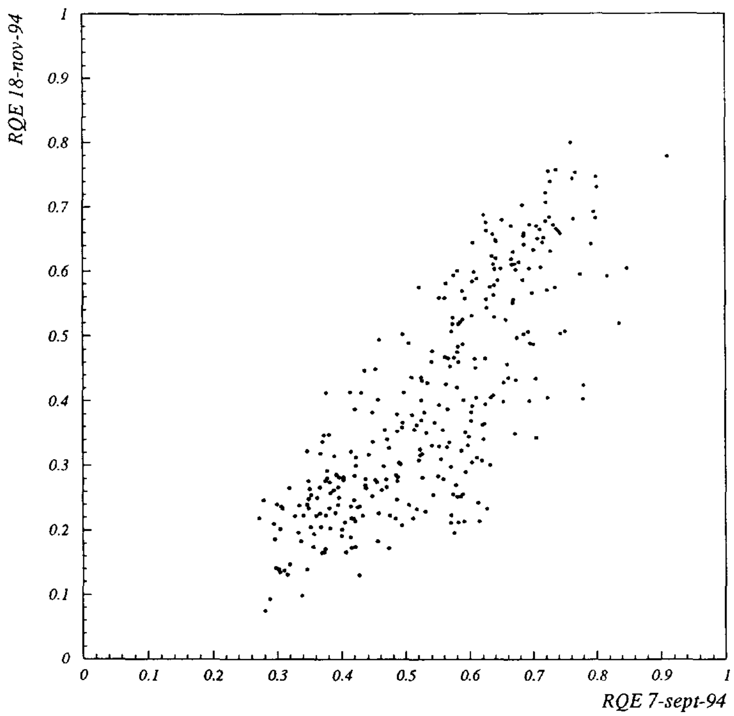

Fig. 7. Scatter plot where a point represents a pixel with the coordinates given by its quantum efficiencies before and after a two-month storage.

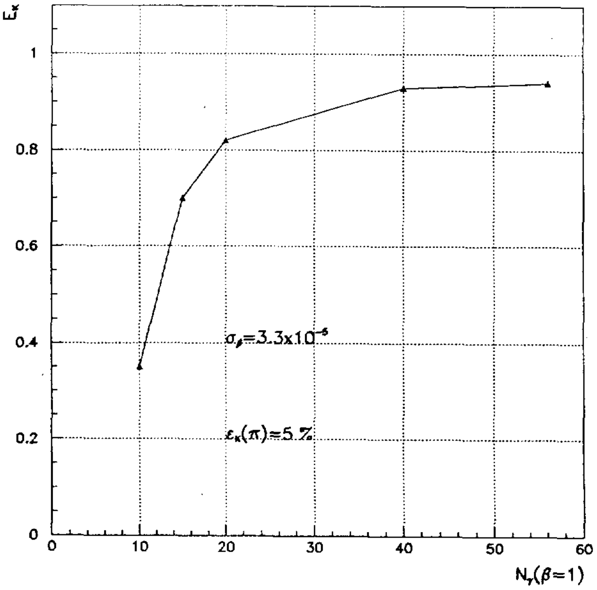

Fig. 8. The kaon identification efficiency (for 5% pion fake probability) depending on the number of detected photoelectrons.

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