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Photon detectors for the HERA-B RICH

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Abstract

Results of tests of different position-sensitive photon detectors for the HERA-B RICH are given. It is observed, that the CsI-MWPC cannot be routinely produced and maintained with sufficiently high quantum efficiency and that the TMAE detector loses anode wire gain too quickly. The third candidate, the H-6568 Hamamatsu multianode PMT, seems to meet all the requirements necessary for photon detection in the HERA-B RICH.

1. Introduction

The HERA-B detector at the HERA e–p collider at DESY in Hamburg, intends to measure CP violation parameters in the B-meson system using thin-strip, fixed targets in the halo of the 820 GeV proton beam [1,2]. B mesons will thus be produced in proton–nucleus collisions and their decays to $J/\psi + K_s^0$ will be measured. Tagging of the B-meson flavour will be performed by identification of the charged kaon into which the associated B-meson decayed. For this purpose a Ring Imaging Cherenkov (RICH) counter will be used. The RICH detector will consist of 2.7 m of perfluorobutane (C_4F_{10}) gas radiator, spherical mirrors of 5.75 m focal length and about 10 m^2 of photon detectors with ~1 cm^2 pixel size. In order to separate kaons from pions up to about 50 GeV/c, the RICH would have to detect at least 20 photons per Cherenkov ring for $\beta = 1$ charged particles. In addition, the RICH signals should be collected in less than the 96 ns bunch crossing time in HERA. The proton–nucleus reaction rate, necessary to detect a few thousand $B \to J/\psi + K_s \to \ell^+\ell^-\pi^+\pi^-$ events in one year, also poses extra demands on the photon detectors. The most exposed parts of the detector would have to operate at a few MHz per channel, which could cause ageing or rate problems. This contribution describes the results of experimental studies of three types of photon detectors as candidates for the HERA-B RICH: a CsI photocathode in a MWPC, a TMAE based detector with 10 cm deep, 8×8 mm^2 unit cells and a Hamamatsu H6568 multianode photomultiplier.

2. The experimental set-up

The details of the experimental set-up have been given elsewhere, so only a short description will be given here.

The detectors were tested with the 3 GeV/c electron test beam T24 at DESY. The Cherenkov radiator was argon gas at normal temperature and pressure, enclosed in a 80 cm diameter, 5 m long aluminium cylinder. The trajectories of the electrons along the cylinder axis were measured with one MWPC on the beam entrance flange and another MWPC on the beam exit flange. A 5 m focal length spherical mirror, kindly obtained on loan from the Omega collaboration, was mounted on the inside of the downstream flange. The Cherenkov photons were thus reflected back to the upstream, entrance flange, where they were focused onto the photon detectors to be tested. Quartz windows on both flanges allowed illumination of the detectors either directly or via reflection from the spherical mirror.

The CsI-MWPC detector [3] is a 24×24 cm^2, asymmetric multiwire proportional chamber. The anode plane consists of 15 μm diameter gold-plated tungsten wires at

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2.5 mm spacing. The cathode wire plane is made of 100 μm diameter Cu–Be wires at 1.25 mm spacing and is separated from the anode plane by a 1.5 mm gap. On the other side, the gap between the anode plane and the CsI photocathode is only 0.7 mm, which allows for a higher signal on the photocathode pads. The photocathode has been made from a printed circuit board with the copper surface segmented into $7.5 \times 7.5\,\mathrm{mm}^2$ pads, which have been electrochemically covered with Sn. On this substrate, a 1 μm thick layer of CsI was finally vacuum evaporated. The gas in the chamber was CH_4 at normal temperature and pressure.

The TMAE detector module [4] consists of 32×32 unit cells, which have $8 \times 8\,\mathrm{mm}^2$ cross section and are 10 cm deep. The cells are separated by gold coated bronze walls and are assembled from slotted sheets. A 25 μm diameter, gold-coated tungsten anode wire is stretched along the axis of each cell, being attached to the G10 backplane on the rear side and a G10 bridge on the photon entry side. On the entry side, the chamber is closed with a 5 mm thick quartz window. The filling gas is methane, of which a chosen fraction is passed through a room temperature TMAE bubbler, so that the TMAE vapour pressure in the chamber is not saturated. Through the backplane, the anode wires are connected to preamplifiers and further to the ARGUS μVDC readout system [5].

Two types of Hamamatsu multianode photomultipliers have been tested: H6568 with a normal window for visible light and H6568-30 with a UV extended window. The top surface of the PMs has dimensions of $28 \times 28\,\mathrm{mm}^2$ with the photosensitive central part $17.5 \times 17.5\,\mathrm{mm}^2$ divided into 16 pads $4 \times 4\,\mathrm{mm}^2$ each. This means that light guides or concentrators would be required in order to eliminate or reduce the effect of the dead surface.

3. Measurements and results

The first part of this section contains a direct comparison of the performance of the CsI-MWPC with the TMAE detector, while the second part gives the results obtained with the multianode photomultiplier.

Estimates, based upon available data for the refractive index of argon, for the transmission of argon gas and the quartz windows, reflectivity of the mirrors, the transmission of the cathode and anode wire planes for Cherenkov light in the case of the CsI-MWPC or absorption in the initial dead layer or the chamber walls for the TMAE detector as well as the quantum efficiency for CsI and TMAE and 90% single photoelectron detection efficiency, result in 22 and 21 expected hits per Cherenkov ring to be measured with the CsI-MWPC and the TMAE detector respectively. Measurements have been performed by mounting both detectors on the beam entrance flange; the TMAE chamber above and the CsI chamber below the beam tracking MWPC. The spherical mirror could be positioned so, that each detector measures a sector of the Cherenkov ring or that the entire ring is within one of the detectors. The results obtained amount to about 11 hits/ring for the TMAE detector and only 6 hits/ring for the CsI detector. Correlations of measurements with both detectors suggest, that the discrepancy with respect to expected numbers is probably due to a reduced gas transparency and/or mirror reflectivity. In addition the CsI quantum efficiency was reduced to 60% of the expected value due to contamination during handling and transportation to DESY.

The drift time spread for the two detectors has been measured and is 65 ns for the TMAE chamber and only 25 ns for the CsI detector, which means that both detectors satisfy the requirement of being faster than the 96 ns bunch crossing time. Good agreement of the measured and simulated drift time distribution for the TMAE chamber suggests that there is no significant source of photoelectrons on the cell walls as well as no significant loss of electrons in the low field in the corners of the cell.

The performance of both detectors at high counting rates has also been measured. The TMAE detector had no special problems with rates as high as 10 MHz/channel. The CsI detector, however, broke down at rates as low as $10\,\mathrm{kHz/cm}^2$, developing a current, which persisted even after the light source was removed. For a symmetric CsI-MWPC or by adding another grounded wire plane above the cathode wires, which are raised to a positive potential of a few hundred volts, the performance improves and problems occur only after some hours of running at the $\mathrm{MHz/cm}^2$ rate. As the same problems arise also in the chamber without the CsI layer, it is believed that the cause lies with the cathode wires.

In the most exposed parts of the HERA-B RICH, a charge of about 1 mC per cm of anode wire would be collected in a few days, which makes the ageing problem quite severe. Fig. 1 shows the normalized current I/I_0, where I_0 is the initial current, the normalized rate and some values of the measured quantum efficiency for the CsI-MWPC as a function of the charge collected per cm^2 of the detector. The similar behaviour of current, rate and

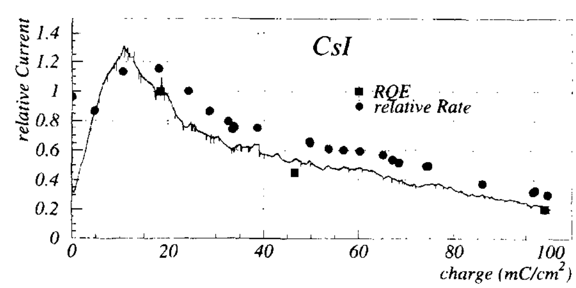

Fig. 1. Ageing of the CsI-MWPC detector. The dependence of the normalized current I/I_0 (full line), of the normalized rate (full circles) and the relative quantum efficiency (full squares) on the accumulated charge per cm^2 of the CsI-MWPC detector.

quantum efficiency suggests that ageing results in a decrease of the quantum efficiency of the CsI photocathode. For the TMAE detector however, ageing results in a decrease of gain due to a reduction of avalanche multiplication as a consequence of deposits on the anode wires. Fig. 2 shows the decrease in gain of the TMAE chamber as a function of the charge collected in one channel (one channel = $0.64\,cm^2$). It is seen that the gain falls to ~50% of its initial value already after 5 mC/channel and keeps on falling. These results agree reasonably with the results obtained by Va'vra [6] for a 33 μm diameter carbon wire in the same gas. The results show that without some improvement (such as recovery of the gain by heating the wires with current), the TMAE chamber would not operate very well in the HERA-B environment.

Given that the CsI-MWPC could not be produced and maintained with a high quantum efficiency and that the TMAE detector aged too quickly, we considered a multianode photomultiplier as a possible photon detector for the HERA-B RICH. From the quantum efficiency values provided by Hamamatsu Company for the photomultipliers H6568 and H6568-30, we estimate that in the test set-up (5 m of argon gas + reflection from the spherical mirror) the PMs, if infinitely extended, should register 23 (H6568) and 39 (H6568-30) hits per ring.

Both PMs have been measured in our test set-up (Fig. 3). Assuming that the photocathodes are infinitely extended, i.e. the entire surface is covered by the photocathode, the measured values correspond to 23 hits/ring and 31 hits/ring for the visible (H6568) and the UV extended (H6568-30) photomultiplier respectively. The agreement with the expected values is satisfactory. As most of the detected light is in the visible region the problem of gas transparency and mirror reflection is less pronounced than was the case for the CsI-MWPC and the TMAE detectors, which are sensitive in the ultra-violet region.

As the photocathode covers only 36% of the PM surface, one would detect only 8 photons/ring (H6568) and 14 photons/ring (H6568-30) if the PMs are closely packed and no light guides or concentrators are used. Studies of the efficiency of such light guides are in progress. The pulse height distribution for single photoelectrons being ejected from the H-6568 photocathode has also been measured and is shown in Fig. 4 for different high voltage values.

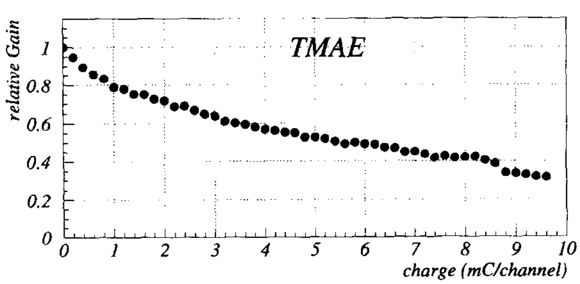

Fig. 2. Ageing of the TMAE detector. The dependence of the anode wire relative gain on the charge collected per channel.

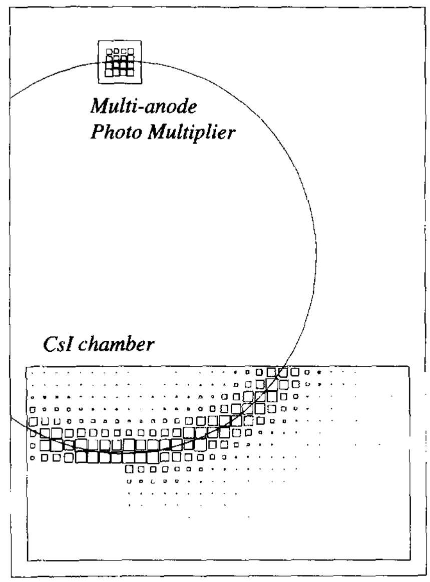

Fig. 3. The distribution of hits for Cherenkov rings intercepted by the CsI-MWPC and the multianode PMT.

4. Conclusions

From the measurements and the results presented, we conclude that both the CsI-MWPC and the TMAE detector do not satisfy the requirements for photon detection in the HERA-B RICH. The CsI-MWPC has quantum efficiency problems, while the TMAE detector ages too quickly. The TMAE could possibly be used in regions where the count rates are sufficiently low and ageing is slow. The Hamamatsu PM type H6568 has sufficiently high quantum

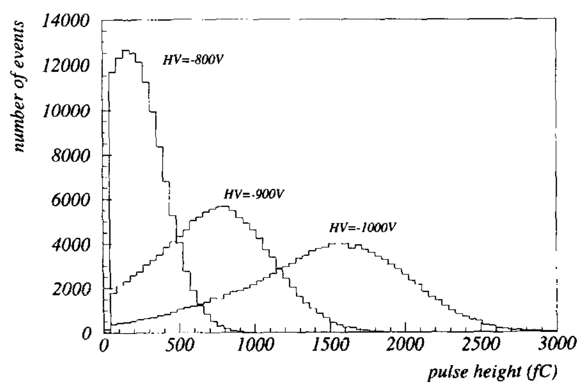

Fig. 4. Pulse height distributions for single photoelectrons ejected from the photocathode of the H-6568 photomultiplier.

efficiency to detect enough photons to guarantee π–K separation up to at least 50 GeV/c. This multianode photomultiplier also seems to meet all the other requirements.

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