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The HERA-B RICH

S. Korpar[a,*], I. Arinyo[b], M. Atiya[c], D. Broemmelsiek[d], J. Carvalho[e], D. Dujmić[f], R. Eckmann[f], L. Garrido[b], A. Gorišek[a], I. Ivaniouchenkov[e], M. Ispirian[g], S. Karabekian[g], P. Križan[a], K. Lau[h], P. Maas[d], J. McGill[f], R. Miquel[b], R. Pestotnik[a], J. Pyrlik[h], D. Ramachadran[h], K. Reeves[f], J. Rosen[d], R. Schwitters[f], M. Starič[a], A. Stanovnik[a], D. Škrk[a]

[a] *J. Stefan Institute and University of Ljubljana, Ljubljana, Slovenia*
[b] *University of Barcelona, Barcelona, Spain*
[c] *BNL, Upton, USA*
[d] *Northwestern University, Evanston, USA*
[e] *LIP Coimbra, Portugal*
[f] *University of Texas, Austin, USA*
[g] *DESY, Hamburg, Germany*
[h] *University of Houston, Houston, USA*

Abstract

The essential components of the ring imaging Cherenkov detector for the HERA-B experiment are briefly described. Results of the first test measurements with the HERA proton beam are presented and the capability of the RICH to identify kaons is estimated. © 1999 Elsevier Science B.V. All rights reserved.

1. Introduction

The HERA-B experiment [1] aims at measuring: CP violation in $B^0 \to J/\psi K^0_S$ and $B^0 \to \pi^+\pi^-$ decays, $B^0_s \bar{B}^0_s$ mixing and $B\bar{B}$ decays with two leptons in the final state. The B mesons will be produced in collisions of 820 GeV/c protons with a fixed target. The target will consist of 8 ribbons in the halo of the proton beam in order not to disturb experiments measuring ep collisions.

One of the essential components of the spectrometer is the ring imaging counter (RICH), with the prime function of separating kaons from pions [2,3]. The identification of kaons serves to tag the flavour of one of the B mesons in the CP violating measurement.

In what follows we shall briefly describe the essential components of the RICH counter and will then discuss recent results obtained with the 820 GeV/c proton beam interacting in the HERA-B targets.

2. Radiator

The 100 m^3 vessel for the C_4F_{10} gas radiator has been constructed out of stainless steel, except for the particle entry and exit windows (1 mm Al) and

* Corresponding author.
E-mail address: samo.korpar@ijs.si (S. Korpar)

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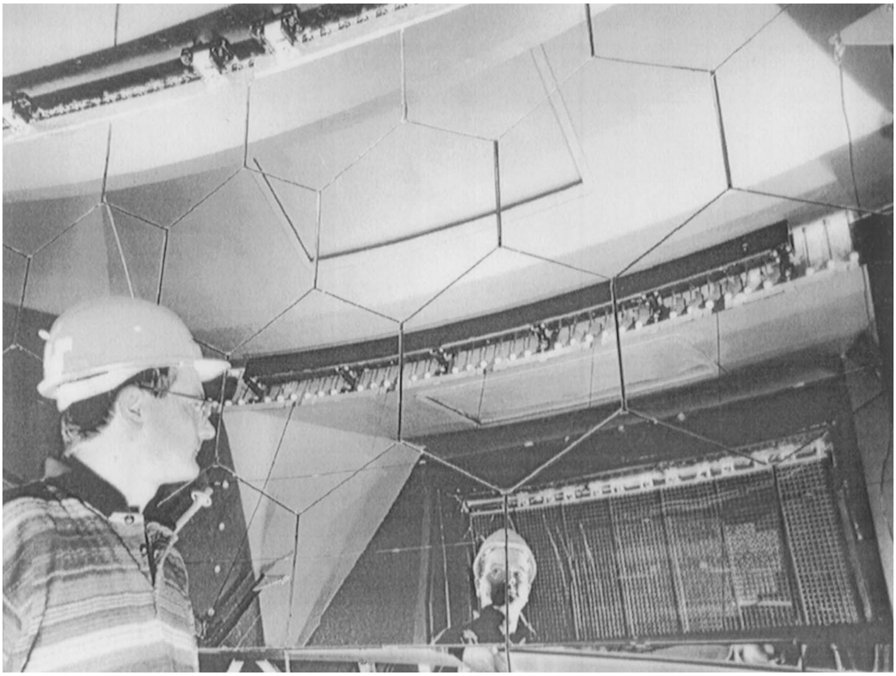

Fig. 1. A photograph of the mirror system.

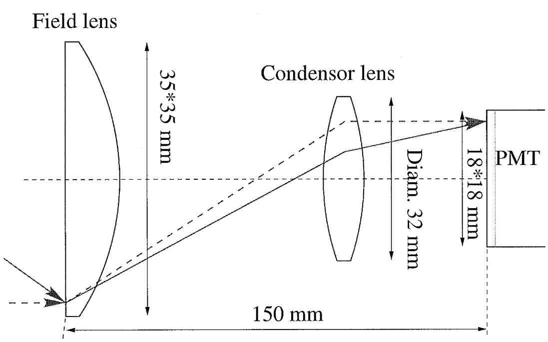

Fig. 2. The optical system for light collection and demagnification.

the photon exit windows (UVT perspex). Also, two beam shrouds close the gas volume around the two beam pipes for protons and electrons.

The purification and circulation system for the C_4F_{10} gas has been constructed at CERN and is being commissioned at DESY. It is worth noting that the initial filling of the volume will amount to about 1100 kg of C_4F_{10}.

3. Mirrors

Two mirror systems, a spherical and a planar one, are made of hexagonal and rectangular units, respectively. The hexagonal mirror segments with 11.4 m radius of curvature have been produced by Glass Mountain Optics from 7 mm thick grinded glass. The mirror quality has been remeasured upon delivery [4]. For each segment the radius of curvature was measured, as well as the fraction of scattered light. In addition, a Ronchi image has been recorded by a camera to check the homogeneity of the mirror surface. The reflectivity is

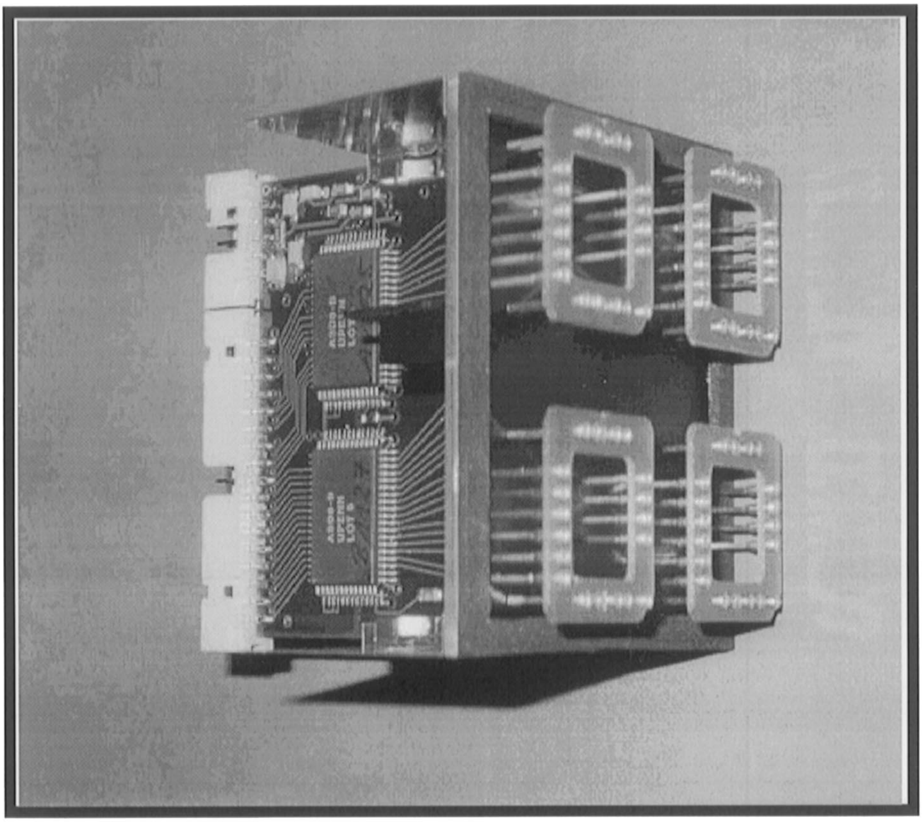

Fig. 3. Base board with PMT sockets and front end electronics.

required to exceed 85% in the wavelength interval 250–600 nm. This was verified by measuring the reflectivity of the two witness samples.

By making use of the data gathered on all the mirror segments, it was possible to group them in the tiling scheme according to their optical quality and resolution requirements [5].

Each spherical mirror segment is supported at three points, two of which can be moved, and are motor driven via a transmission mechanism with a feed through to the exterior of the vessel.

The planar mirrors are made of float glass, thus being significantly cheaper at the required optical quality.

A photograph of the mirrors as mounted in the radiator vessel is seen in Fig. 1.

4. Photon detector

The initially foreseen detectors based on wire chambers had to be abandoned; the TMAE detector showed a prohibitive decrease of avalanche gain due to aging effects, while the CsI photocathode could not be routinely produced and maintained with sufficiently high quantum efficiency in addition to problems with rates in excess of a few kHz per pixel. The final photon detector thus consists of Hamamatsu multianode R5900 M16 and M4 photomultiplier tubes. Due to the smaller photocathode surface compared to the photomultiplier cross section, a two lens demagnification system (2 : 1) was designed in order to adjust the required pixel size to the PMT pad size (Fig. 2). The

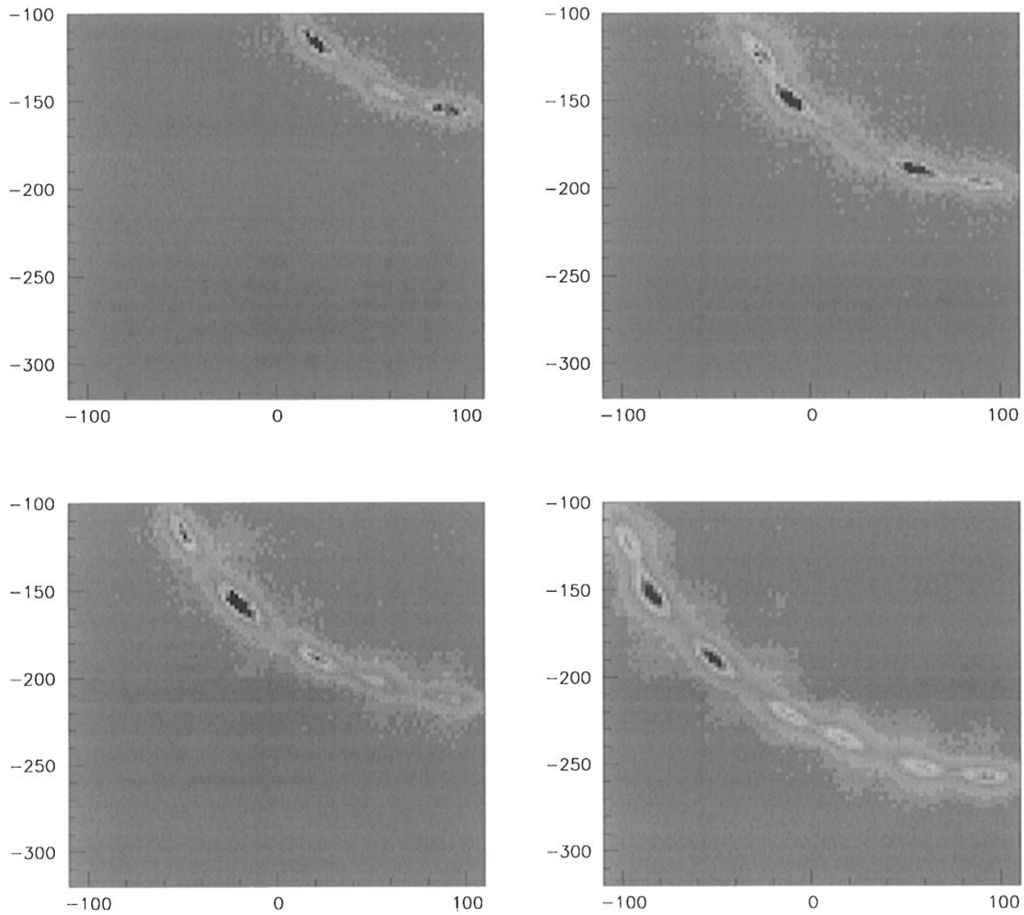

Fig. 4. Cherenkov rings of 3 GeV/c electrons as the argon gas radiator is progressively replaced by the C_4F_{10} gas.

granularity of the photon detector has been chosen on the basis of expected occupancy and the required position resolution to be either 9×9 or 18×18 mm^2. Recent tests have shown satisfactory performance under an elevated counting rate of 3 MHz per channel during a period of 30 days [6].

The required demagnification of a factor of 2 is achieved with a two lens system consisting of a field lens and a condensor lens as is shown in Fig. 2 [7]. The lenses are made by WAHL Kunststoffoptik GmbH of UVT perspex with high transparency over most of the wavelength region where the photocathode is sensitive [4]. The angular acceptance of the optical system is also satisfactory and is uniform for incident angles below about 110 mrad [4].

The base board with sockets for the multianode photomultipliers and front end electronics is shown in Fig. 3. The base board accepts four PMTs and provides positioning. In addition it houses the voltage divider, signal lines and the front-end electronics consisting of a 16-channel board based on the ASD8 chip.

In order to reduce the contribution of spherical aberration to the overall resolution of the Cherenkov angle, an optimal surface of the Cherenkov

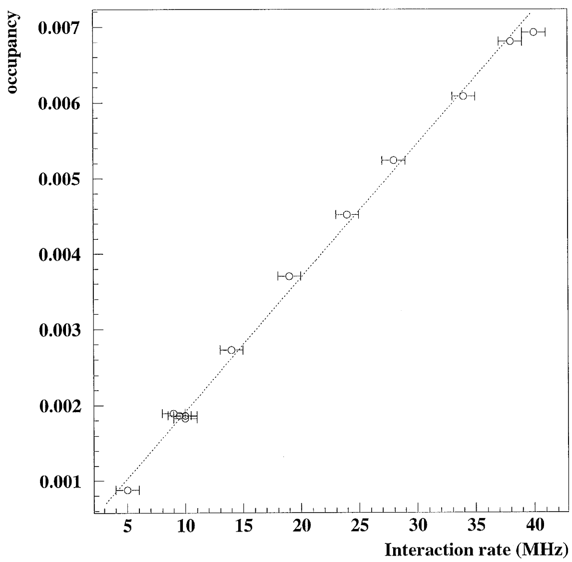

Fig. 5. The count rate on a partly equipped photon detector versus interaction rate in the HERA-B targets.

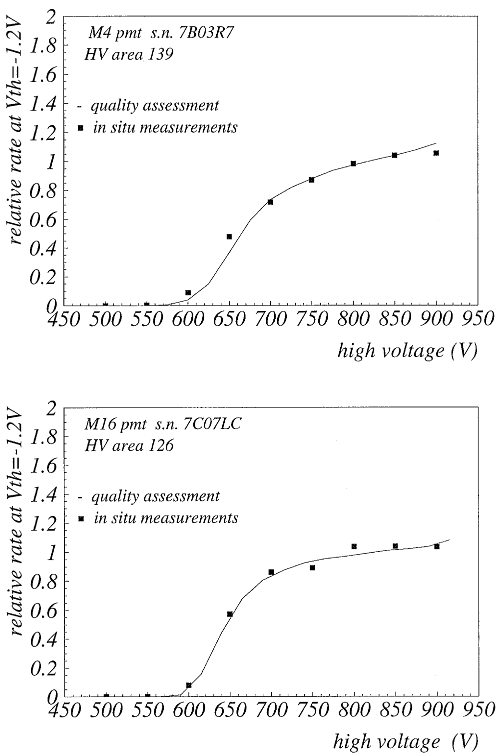

Fig. 6. Count rate versus high voltage for an M4 (top diagram) and M16 (lower diagram) photomultiplier.

photon detector has been calculated [8]. Each half-detector (upper and lower) consists of 5 flat supermodules placed in order to approximate the optimal surface, which is close to the shape of a flattened (ellipsoidal) cylinder. Such an arrangement also ensures better acceptance for the Cherenkov photons, which should be incident onto the flat supermodules at angles below 110 mrad.

5. Test measurements

An array consisting of 36 ($= 6 \times 6$) M16 photomultipliers has been tested with 3 GeV electrons in 5 m of argon gas radiator at the T24 test beam in DESY. Fig. 4 shows a sector of the measured Cherenkov ring with the ring radius growing while the argon gas is being substituted with the C_4F_{10} radiator. The number of detected photons scaled to the full ring with complete photocathode coverage, increased from 21 for pure argon to 72 after 28 h of flushing with C_4F_{10}. These numbers correspond to a figure of merit $N_0 = 70\ \mathrm{cm}^{-1}$ for the test apparatus.

The full set of 1500 M16 and 750 M4 Hamamatsu R5900 photomultipliers has been tested on the bench. The individual channel count rate due to Cherenkov radiation caused by a ^{90}Sr source in a quartz radiator has been measured as a function of high voltage and threshold. On the basis of these tests, the photomultipliers have been grouped according to similar HV characteristics, so that all PMTs within a group could be set to the same high voltage value. Monte Carlo calculations of occupancy and resolution indicated that the outer region of the RICH photon detector could be occupied by M4 PMTs ($9 \times 9\ \mathrm{mm}^2$ pad), while M16 PMTs ($4.5 \times 4.5\ \mathrm{mm}^2$ pad) should be used for the central part.

With the photon detectors in their proper position in the HERA-B spectrometer, the photomultipliers cabled to the readout system and with air as Cherenkov radiator, some data have been taken. Fig. 5 shows the linear dependence of the Cherenkov photon count rate on the proton interaction rate in the HERA-B targets. Fig. 6 gives the count rate versus high voltage for one M16 and one M4 photomultiplier. It is seen that the curves measured

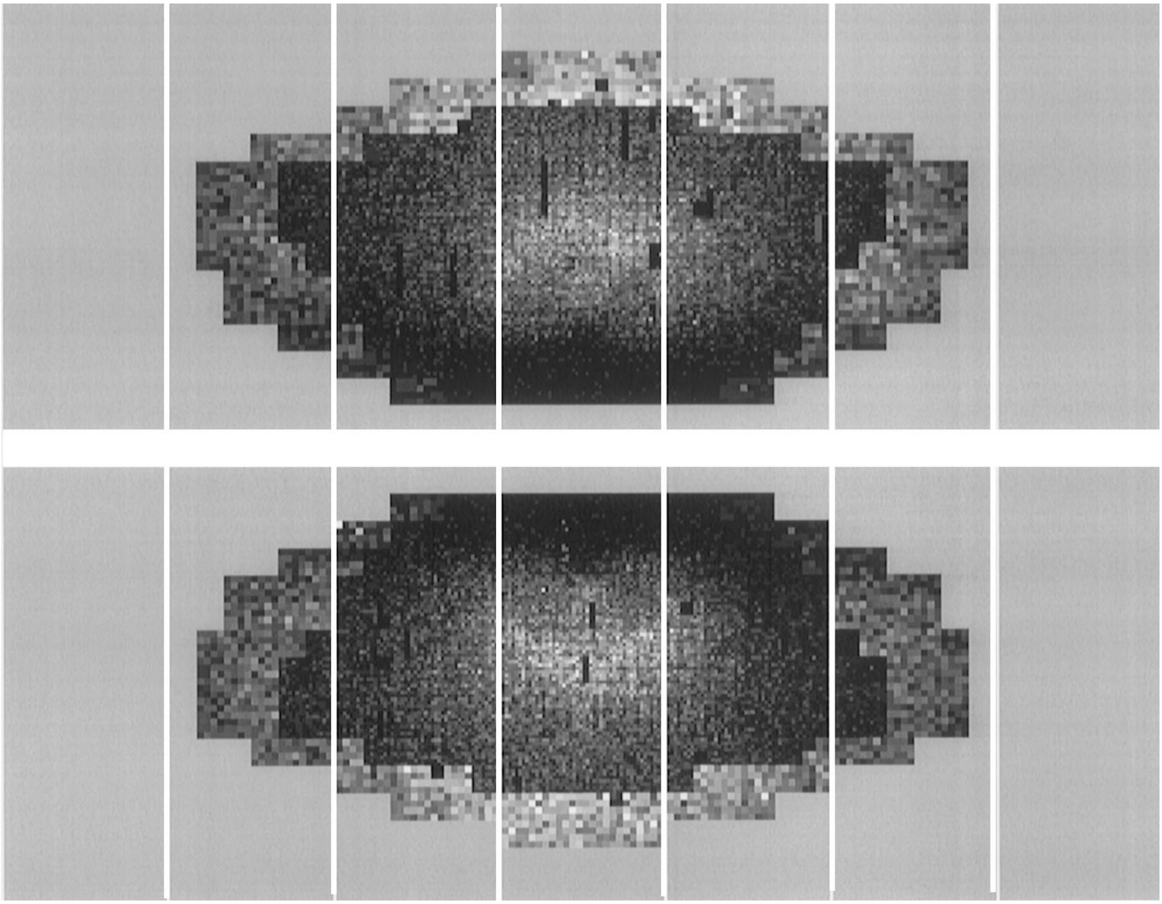

Fig. 7. The occupancy of the upper and lower photon detectors shows the region occupied by M16 (inner region) and M4 PMTs (outer region).

in-situ with the HERA proton beam agree nicely with the ^{90}Sr source measurements. The occupancy is shown in Fig. 7, where the region occupied by M16 PMs is clearly distinguished from the region occupied by M4 PMs.

Some events obtained by a random readout trigger are shown in Fig. 8. In most events Cherenkov rings can be seen by the naked eye. Especially interesting is the event in the lowest image of Fig. 8, where the ring consists of some 15 hits, which is about two times the expected number. The interpretation is that this ring is due to an electron–positron pair with nearly coincident tracks.

6. Conclusions

On the basis of tests described above, we expect to detect 32 ± 2 photons per ring of a $\beta = 1$ particle, when the radiator vessel is filled with C_4F_{10}. This corresponds to a figure of merit $N_0 = 42\ \mathrm{cm}^{-1}$ and should allow identification of kaons up to momenta of at least 50 GeV/c.

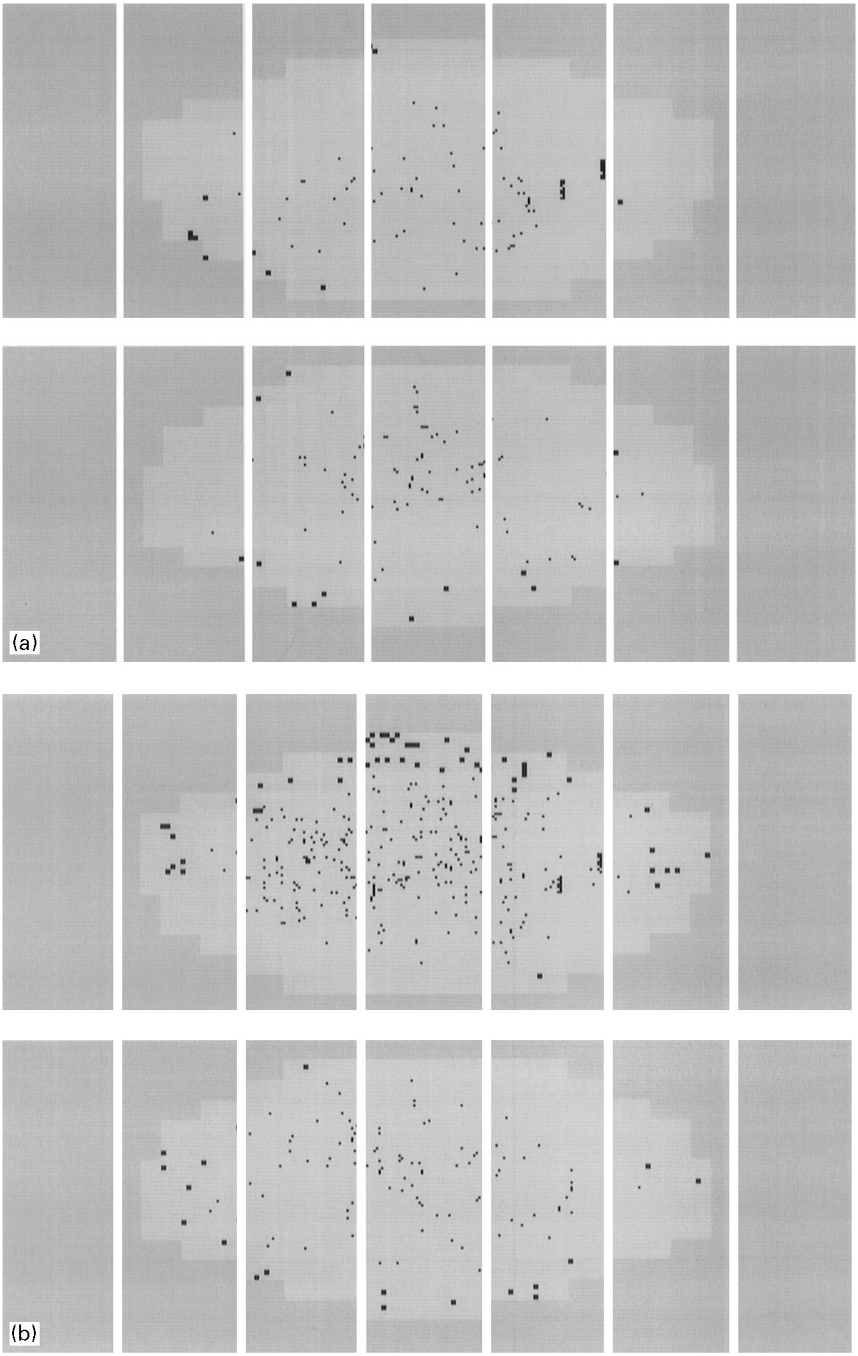

Fig. 8. Display of three events as registered by the upper and lower photon detectors.

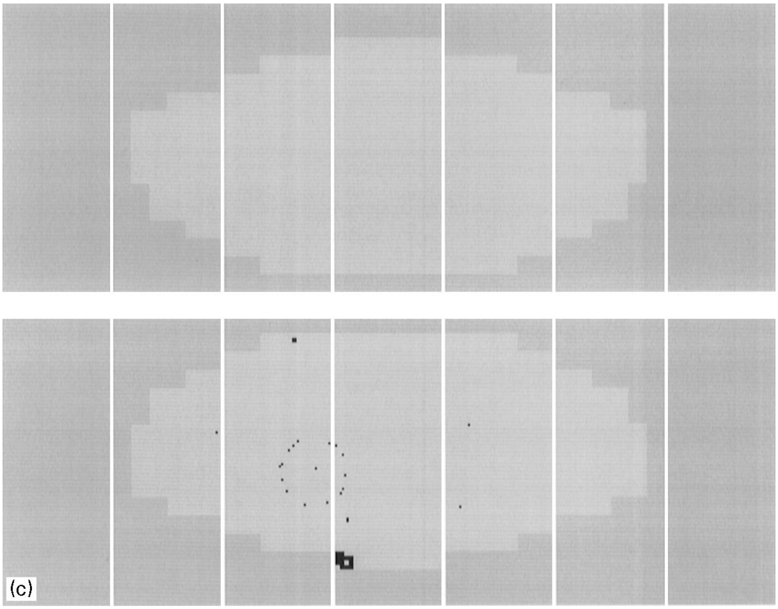

Fig. 8. Continued.

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