The HERA-B RICH

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Abstract

The status of the RICH counter currently under construction for the HERA-B experiment is reviewed. Results of tests of various detector components in particular tests of the photon detector, the light collection system and the read-out chain are presented.

I. Introduction

The HERA-B experiment 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. The identification of kaons serves to tag the flavour of one of the B mesons in the CP-violating measurement.

The counter is under construction at the DESY laboratory. In what follows we shall briefly discuss the essential components of the counter, and will then concentrate on the photon detector and the optical system. After a discussion of recent test results we shall finish by presenting the expected performance and the program of measurements in the next two years.

II. Radiator gas vessel

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 photon exit windows (UVT plexiglass). Two beam shrouds close the gas volume around the two beam pipes for protons and electrons. The vessel is currently under tests for possible gas leaks.

The purification and circulation system for the C_4F_{10} gas is under construction at CERN. It is worth noting that the initial filling of the volume will amount to 1100 kg of C_4F_{10}.

III. Mirrors

The two mirror systems, the spherical and the planar one, are made of hexagonal and rectangular units, respectively. The hexagonal segments of the spherical mirror with 11.4 m radius of curvature have been quality assessed upon delivery. For each segment the radius of curvature was measured, as well as the fraction of scattered light (Fig. 1). In addition, a Ronchi image was recorded by a camera to check the homogeneity of the mirror surface. The reflectivity, required to exceed 85% in the wavelength interval 250 nm - 600 nm, is checked by the coater by measuring the reflectivity of two witness samples (Fig. 1).

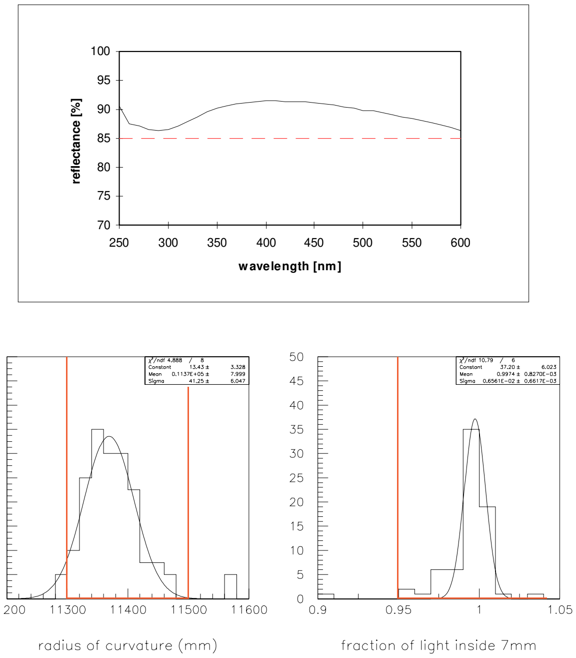

Fig. 1 *Spherical mirrors quality assessment: reflectance of one of the mirrors (top), radius and optical quality, together with indicated acceptance cuts for all mirrors (bottom).*

By making use of the data gathered on all the mirror segments, it was then possible to group them in the tiling scheme according to their optical quality and resolution requirements [1].

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 for the required optical quality.

IV. Čerenkov photon detector

A. Detection method

The initially foreseen detectors based on wire chambers were 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 [2, 3]. The final photon detector thus consists of Hamamatsu R5900 M16 and M4 photomultipliers for which it was proven that they can be used for single photon counting with a high efficiency and very low cross-talk [4]. 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. The granularity of the photon detector has been chosen on the basis of expected occupancy and the required position resolution. It is either 9 x 9 mm^2 or 18 x 18 mm^2 (see Fig. 2). Recent tests have shown very good performance under an elevated counting rate of 3 MHz per channel during a period of 30 days.

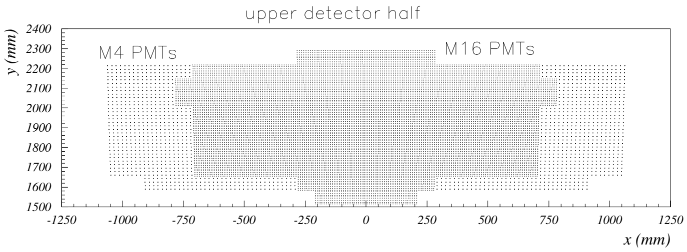

Fig. 2 *Photon detector granularity: one of the possible tiling schemes.*

B. Optical system

The required demagnification of a factor of 2 shall be achieved with a two lens system consisting of a square field lens and a round condenser lens as is shown in Fig. 3. The lenses will be made of UVT plexiglass. The measured performance [5] of the two-lens system is shown in Fig. 4, and is in good agreement with the expectations [6]. Fig. 4 shows that angular acceptance of the optical system from which it may be seen that it is approximately constant for incident angles below about 120 mrad.

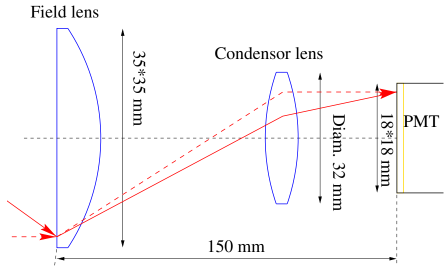

Fig. 3 *Light collection system.*

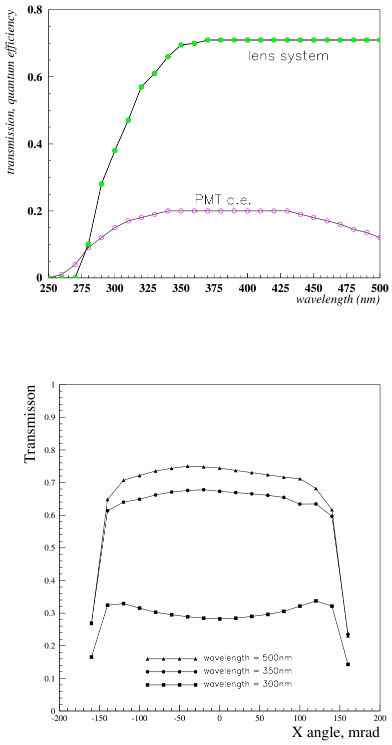

Fig. 4 *Optical system performance: transmission vs. wavelength for perpendicular incidence (above), angular acceptance (below).*

C. Read-out electronics

The base board with sockets for the multianode photomultipliers and front end electronics is shown in Fig. 5. 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 with the ASD8 chip [7].

D. Photon detector surface

In order to reduce the contribution of spherical aberration to the overall resolution of the Čerenkov angle, an optimal surface of the Čerenkov photon detector has been calculated [8]. Each half-detector (upper and lower) will consist of 5 flat supermodules placed approximately on the optimal surface, which is close to the shape of a flattened (ellipsoidal) cylinder. Such an arrangement also ensures better acceptance for Čerenkov photons, which should thus be incident onto the

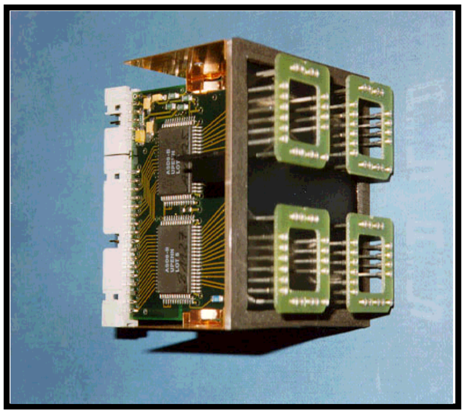

Fig. 5 *Base board with PMT holders and front end electronics.*

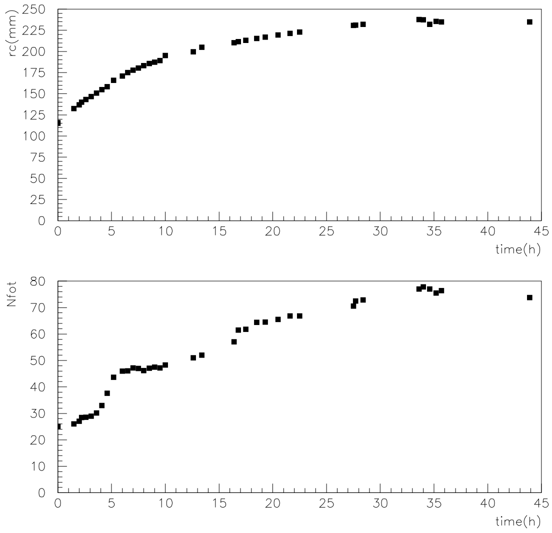

Fig. 7 *Ring radius and the number of detected Čerenkov hits for a fully equipped ring, both as a function of flushing time. The flushing was stopped at around 33 hours.*

flat supermodules at angles below 110 mrad.

V. Results of recent test measurements

A. Test beam measurements

Beam tests with 3 GeV electrons at the T24 test beam at DESY give a figure of merit $N_0 = 70\ cm^{-1}$, which corresponds to about 21 detected photons for a $\beta = 1$ particle in 5 m of argon gas at normal temperature and pressure. The results obtained with an array of PMTs is seen in Fig. 6 [9]. The raw data are represented on the left hand diagram, where the magnitude of the square corresponds to the number of hits in the relevant pixel. The right hand side diagram shows the accumulated Čerenkov ring obtained from the photon hits and from the incident electron track as measured with multiwire proportional chambers.

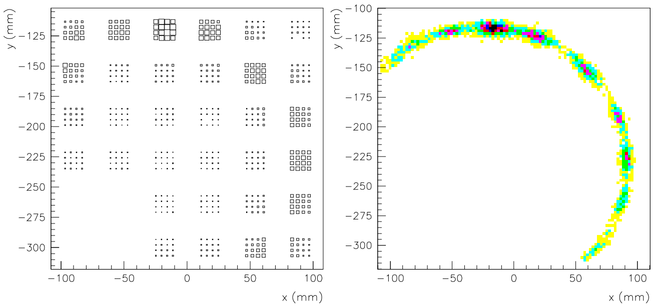

Fig. 6 *Accumulated Čerenkov ring on the photon detector, with argon gas as radiator: raw data (left), using tracking information (right).*

An interesting result is shown in Fig. 7. At t = 0, the argon-filled tank has been started to be flushed with C_4F_{10}. As can be seen, both the Čerenkov ring radius and the detected number of photons start to increase as the gas mixture gets progressively more favourable.

From these results together with measurements of the light collection efficiency and mirror reflectivity, the expected number of detected Čerenkov photons in the final detector amounts to 27. The results of a Monte Carlo calculation, shown in Fig. 8, indicate that under these conditions a total kaon identification efficiency of 75% with 5% pion misidentification probability could be achieved.

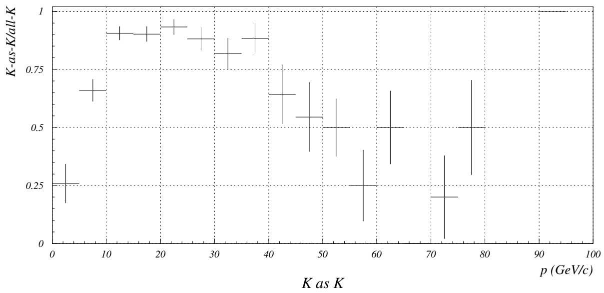

Fig. 8 *Kaon identification efficiency at 5% pion misidentification probability for tagging kaons.*

B. Performance in the HERA-B environment

To verify the performance of the read-out chain in the high rate environment, a prototype supermodule of the photon detector was equipped with the full read-out chain and mounted close to the final position in the HERA-B area. Sheets of plexiglass were used as radiators. The system behaved stably, and showed a consistent relation between the observed rate and the interaction rate if the wire target was varied (Fig. 9). In particular, no additional cross-talk could be observed in excess to what was seen in the test beam measurements. It has been seen that the signal cables perform well even without the need for additional shielding.

VI. Outlook and timetable

Before the end of this year a test of the full system (supermodule with light collection system and read-out electronics) is foreseen in the test beam.

In the long shutdown (December 1997 - May 1998) of the

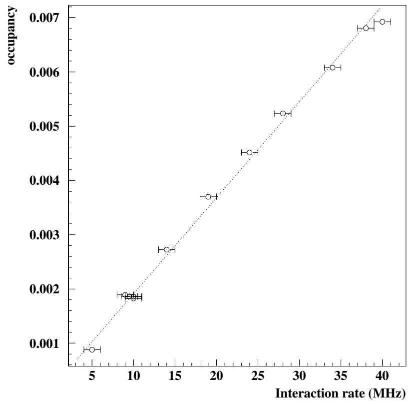

Fig. 9 *Rate on photon detector vs. HERA-B interaction rate.*

HERA machine, we expect to have the RICH counter fully equipped. The mirror system will be initially aligned by using a theodolite. Summer 1998 will be devoted to the commissioning of the detector, and a refined alignment will be carried out by using recorded data [10]. Performance studies will be done with muons as identified in the muon system, and electrons, identified in the electromagnetic calorimeter. It is further expected that the RICH will contribute to the measurement of the $b\bar{b}$ production cross section.

In 1999 we should therefore start running for CP.

VII. References

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