Tests of a proximity focusing RICH with aerogel as radiator

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Abstract— **A study was carried out to measure the performance of a proximity focusing RICH with aerogel as radiator and multianode PMTs as detectors of Čerenkov photons. To increase the active area, a light collection system using a single lens per PMT tube was employed. The yield and resolution were measured by using cosmic rays.**

I. Introduction

The use of aerogels as Čerenkov radiators has been limited up to recently mainly by its low transparency for light and the fact that aerogels are hygroscopic. New methods of synthesis and improved manufacturing procedures have made available aerogels with better transparency and some are even hydrophobic [1], [2], [3]. This allows the use of aerogel Čerenkov radiation in developing detection methods for identifying and separating different species of particles. The BELLE experiment uses aerogel as a radiator in the threshold Čerenkov counter [4], while Čerenkov rings are observed in the HERMES experiment [5]. The idea of using aerogels in proximity focusing RICH detectors has been discussed recently as a possible update of the BELLE particle identification system [6]. The advantage of such a detector is its compactness, which is especially important for experiments at colliders. By making use of our experience with multi-anode photomultipliers as single photon detectors [7] and optical systems for light collection [8], we constructed a test apparatus to study the yield and resolution as described below.

II. The experimental set-up

The apparatus for measuring Čerenkov photons emitted by cosmic rays consists of an aerogel radiator, 16 multianode photomultipliers (all contained in a light tight box), a MWPC tracking system and an electronic readout system (Fig.1). Three 10×10 cm^2 multiwire chambers with 20 μm diameter gold-plated tungsten anode wires at 2 mm pitch and with 90%Ar + 10%CH_4 gas flow, are read out by delay lines on the x and y cathode wires. The cosmic particle straight track is thus reconstructed from the three hit coordinates. After traversing the tracking system and the scintillation counter, the particle enters the aerogel radiator, where it emits Čerenkov photons, which are detected by a 4×4 array of multianode photomultiplier tubes. The photomultiplier tubes employed are of the Hamamatsu R5900-00-M16 type with sixteen 4.5×4.5 mm^2 square anode pads, read out in groups of four to form the effective area of each photon detector pad of approximately 9×9 mm^2 in size. Since the photocathode sensitive surface is 18×18 mm^2 and the pitch between PMTs is 36 mm, the photocathodes cover only about 25 % of the detector area. In order to increase the active area of the detector, a 36×36 mm^2 UV quality perspex lens, with 4.8 cm focal length [8],

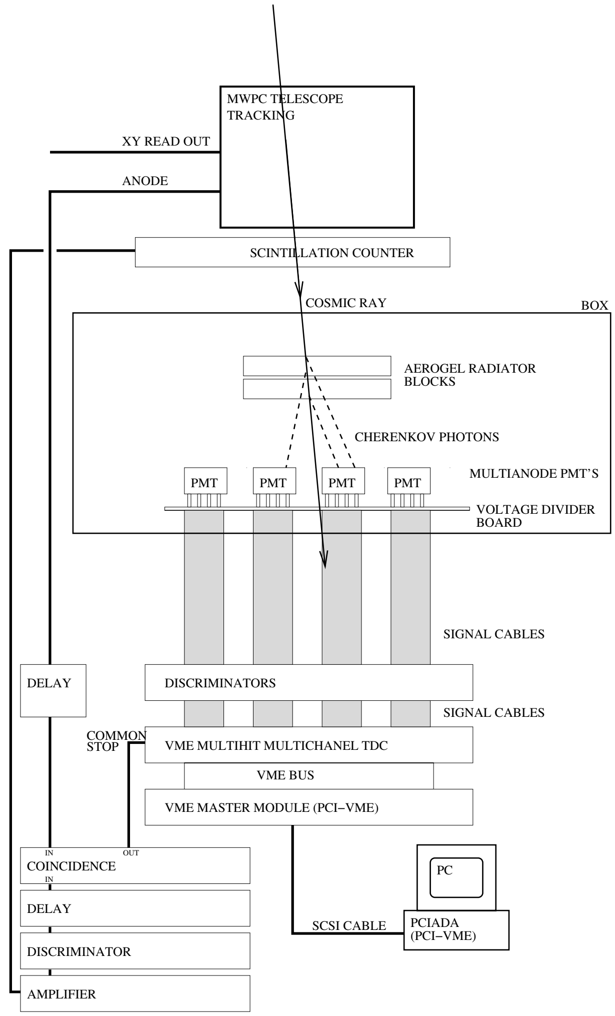

Fig. 1. Experimental set-up

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was placed in front of each PMT, 2.4 cm from its window (Fig.2). This lens system, which covers the entire detector area, is expected to focus incident photons onto the pho-

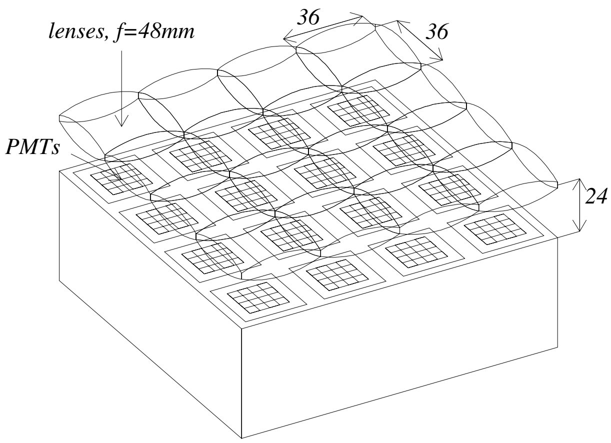

Fig. 2. A 4x4 PMT module with a single-lens light collection system.

tocathode sensitive surface thus increasing the number of detected Čerenkov photons. The PMTs are plugged into voltage divider boards inside the light tight box, with the signals passing through connectors to the readout system located outside the box. The PMT anode signals are first discriminated and then recorded by a VME multihit, multi-channel TDC, for which the COMMON STOP is provided by the MWPC anode signal in coincidence with the scintillation counter signal. The TDC signals are stored for later analysis in a personal computer via the PCI-VME system (Fig.1)

III. Measurement and analysis

Measurements have been performed with and without the lens system for two different aerogel radiators; one having n = 1.05 ($\theta_{\rm ch}^{\beta=1}$ = 313 mrad, ρ = 0.175 g/cm^3, d = 20 mm, $\lambda_{\rm abs}$ = 15 mm), the other with n = 1.03 ($\theta_{\rm ch}^{\beta=1}$ = 234 mrad, ρ = 0.106 g/cm^3, d = 23 mm, $\lambda_{\rm abs}$ = 38 mm), both produced with the method discussed in [1].

The distribution of events with respect to the number of photons detected within 2σ of the expected Čerenkov ring, is shown in Fig.3 and Fig.4 for both aerogel radiators and for the photon detector with or without the lens system. It may be seen that the lens system increases the average number of detected photons. In order to compare these distributions with expectations, a simulation is in progress, which will take into account the angular and velocity distributions of incident cosmic particles, the generation, scattering and absorption of Čerenkov photons in the aerogel, reflection, refraction and absorption in the lens system, as well as the geometric acceptance of the photocathodes, their quantum efficiency and photoelectron collection efficiency. The acceptance of the lenses depending on photon incident angle for three photon wavelengths has been calculated and is shown in Fig.5.

Distributions of photon hits with respect to their corresponding Čerenkov angle, are shown in Fig.6. It may be seen that using the lenses in order to increase the number

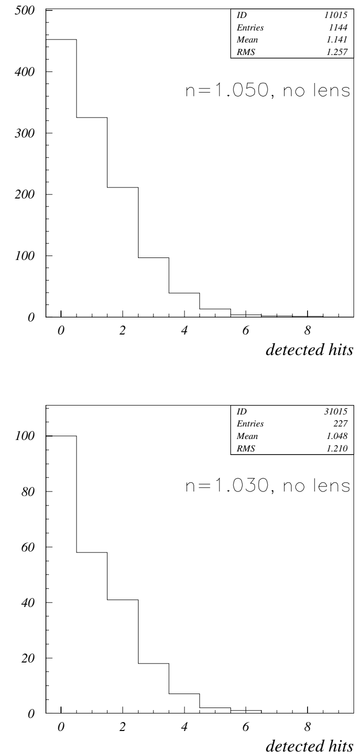

Fig. 3. Distributions of events with respect to the number of detected Čerenkov photons for both radiators and the sistem without lenses.

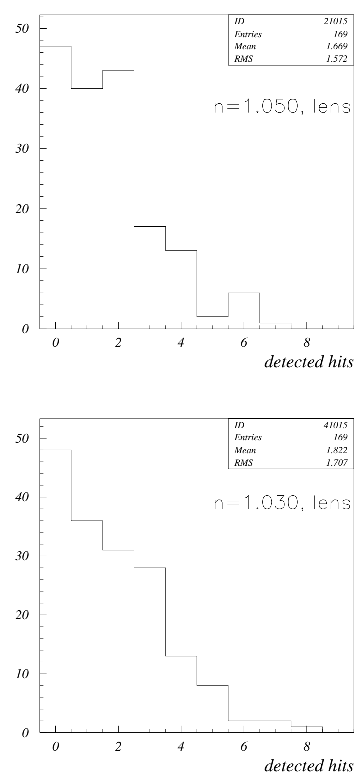

Fig. 4. Distributions of events with respect to the number of detected Čerenkov photons for both radiators and the sistem with lenses.

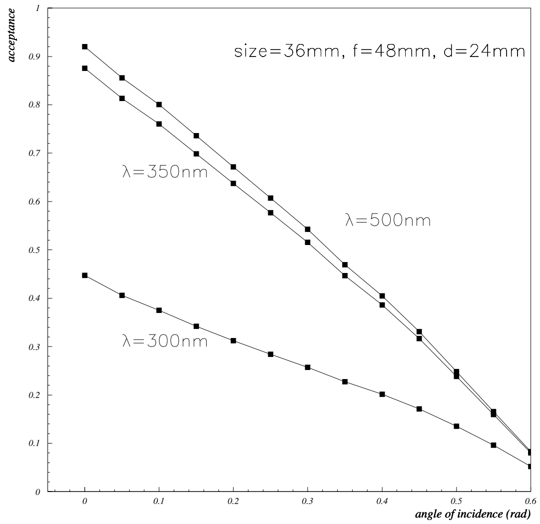

Fig. 5. Acceptance of the light collection system as determined by ray tracing using measured transparency data.

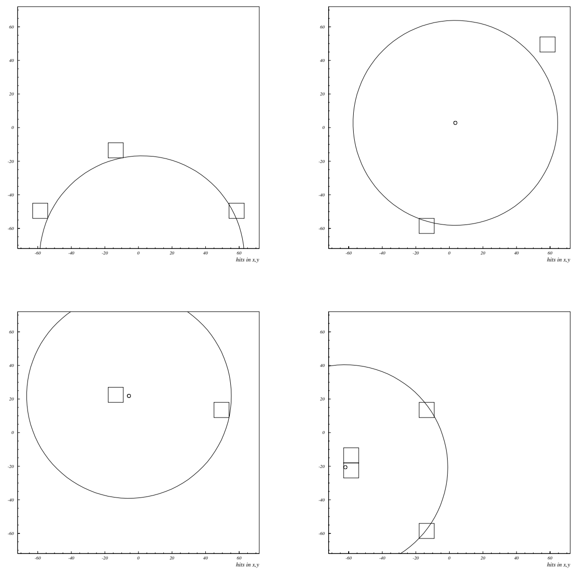

Fig. 7. Some examples of event hit paterns. The circle corresponds to the Čerenkov ring of a β =1 particle given by the measured track direction.

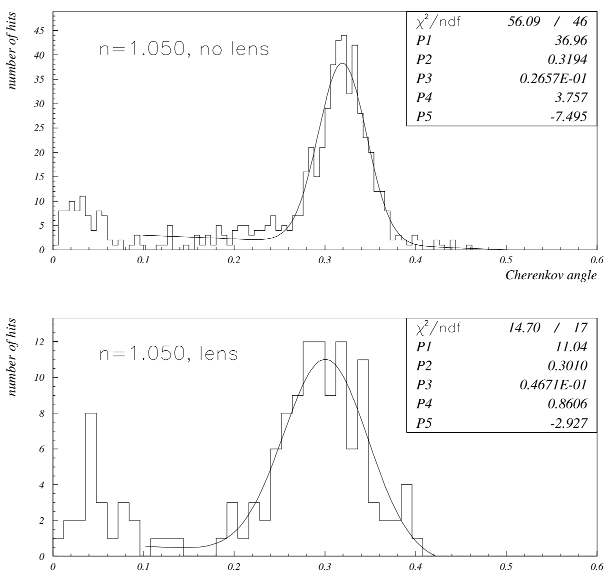

Fig. 6. Distribution of hits with respect to their corresponding Čerenkov angle for the n=1.05 radiator and the system with and without lenses. Fit parameters correspond to the amplitude, mean and width of the Gaussian, and the constant and slope of the background distribution.

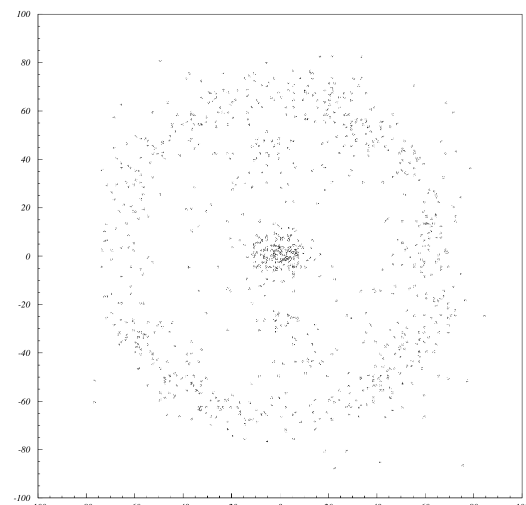

Fig. 8. Accumulated hit distribution for selected cosmic ray particles incident along the axis of the apparatus.

of detected photons also increases the width of the peak. An expected broadening of the peak is due to the increased pixel size ($\sigma_{\rm pix}^{\rm nolens} = 12.5$ mrad $\rightarrow \sigma_{\rm pix}^{\rm lens} = 25$ mrad). Of the other contributions to the single photon Čerenkov angle resolution, dispersion in the aerogel and in the lenses, track direction and uncertainty of emission point, only the last is non-negligible ($\sigma_{\rm emp} = 9$ mrad). These numbers however do not succeed in reproducing the measured values ($\sigma_{\rm exp}^{\rm nolens}$ = 27 mrad and $\sigma_{\rm exp}^{\rm lens} = 47$ mrad). In addition we observe a shift in the position of the Čerenkov peak, when using lenses as compared to the results without lenses. Both of these discrepancies might have a common origin, which is being investigated.

Finally, we give in Fig.7 examples of some events, and in Fig.8 the accumulated hit distribution for events with incident particles near the axis of the apparatus.

IV. Conclusions

An apparatus for investigating the capabilities of a proximity focusing Čerenkov detector based on multiwire proportional chambers, aerogel radiators and multianode photomultipliers, has been constructed and a lens system for increasing the acceptance of Čerenkov photons is being studied. Although initial results show that the lenses do increase the number of detected photons, detailed comparisons with simulation remain to be performed. Additional problems concerning the resolution, i.e. the width of the peak in the single Čerenkov photon angular distribution, which is not in agreement with estimates, remain to be solved. Further work, which should give answers for the performance figures such as average number of detected photons and acheivable resolution, is in progress.

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