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Proximity focusing RICH detector based on multilayer silica aerogel radiator

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ABSTRACT

The performance of a proximity focusing Ring Imaging Cherenkov detector equipped with a radiator of silica aerogel is presented. The aerogel tile used is a monolith with variable index of refraction. Cherenkov photons are detected with high granularity by eight Hamamatsu H9500 flat panel multi anode phototubes.

1. Introduction

Ring Imaging CHerenkov (RICH) detectors with silica aerogel radiators (refractive index in the range $n = 1.01-1.07$) are widely used for the identification of particles of momentum in the few GeV/c range. If the space constraints forbid the use of focusing mirrors, proximity focusing devices are employed. In these detectors an increase of the radiator thickness while enhancing the Cherenkov photoelectron yield increases the contribution (σ_t) to the resolution of the Cherenkov ring radius. To overcome this problem, single aerogel tiles, made of several layers with different refractive index (multilayer) can be a solution. The multianode photomultipliers (MAPMT) with pixel size less than 9 mm^2 are used to minimize the contribution to the resolution (σ_p) due to the granularity of the photodetectors. This paper describes also a custom electronics associated to the MAPMTs.

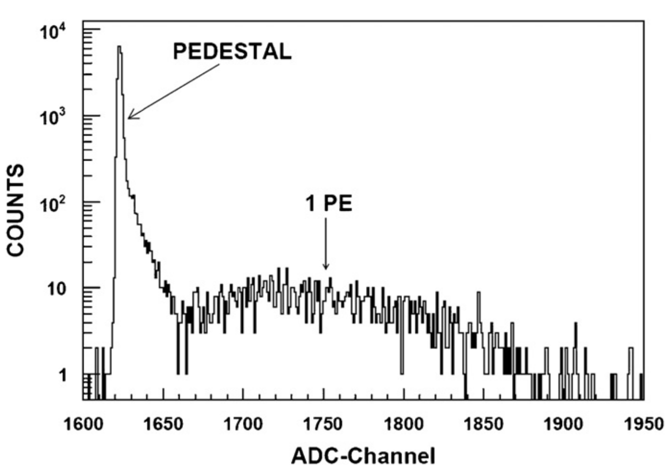

Fig. 1. The single photoelectron spectrum in one H9500 channel.

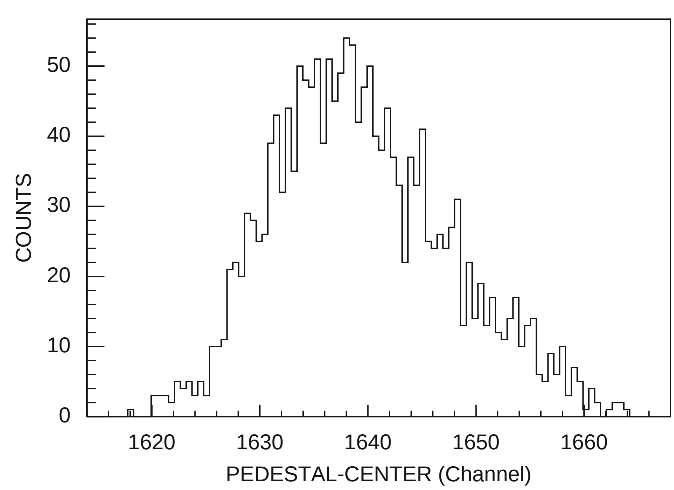

Fig. 2. The pedestal position distribution of eight H9500 channels.

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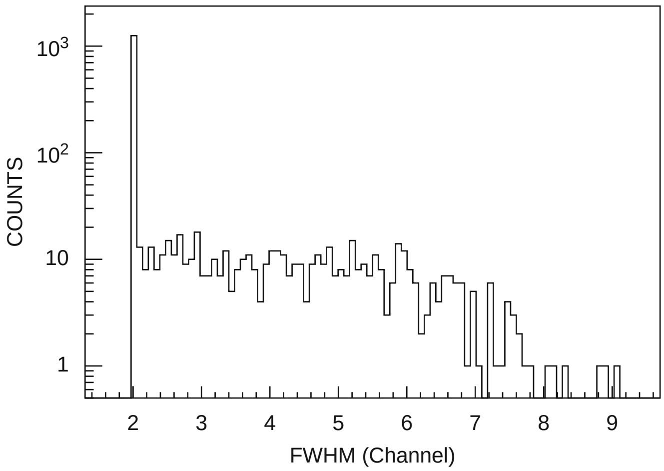

Fig. 3. The pedestal FWHM distribution of eight H9500 channels.

2. Experimental set-up

The multilayer aerogel tested in this paper has three layers (first layer: $t = 12.6$ mm thick, $n = 1.045$; second: $t = 13.2$ mm, $n = 1.038$; third: $t = 15.2$ mm, $n = 1.033$). A matrix of eight Hamamatsu H9500 MAPMTs, readout with custom electronics, has been used as photodetectors. The proximity focusing RICH so assembled has been exposed to 500 MeV/c electrons at the Frascati Beam Test Facility.

The anode plane of a H9500 is segmented in 256 channels, each 2.8×2.8 mm^2 in size, with a pitch size of 3.04 mm. The excellent packing factor (89%) and the effective wavelength range of its bialkali photocathode (maximum quantum efficiency at 420 nm) make these MAPMTs valid tools for the detection of single photons in small surfaces. The readout system is built around the MAROC2, a VLSI 64-channel front-end chip, with self-triggering capability and multiplexed output of the channels. Each chip channel, directly connected to one PMT channel, is made of a preamplifier with a variable gain and a low input impedance, a fast shaper with an adjustable discriminator threshold to generate a trigger pulse, and a slow shaper with a circuit to store the analog value of the input charge. Each channel has its own digital trigger output. The analog channel values are extracted individually and

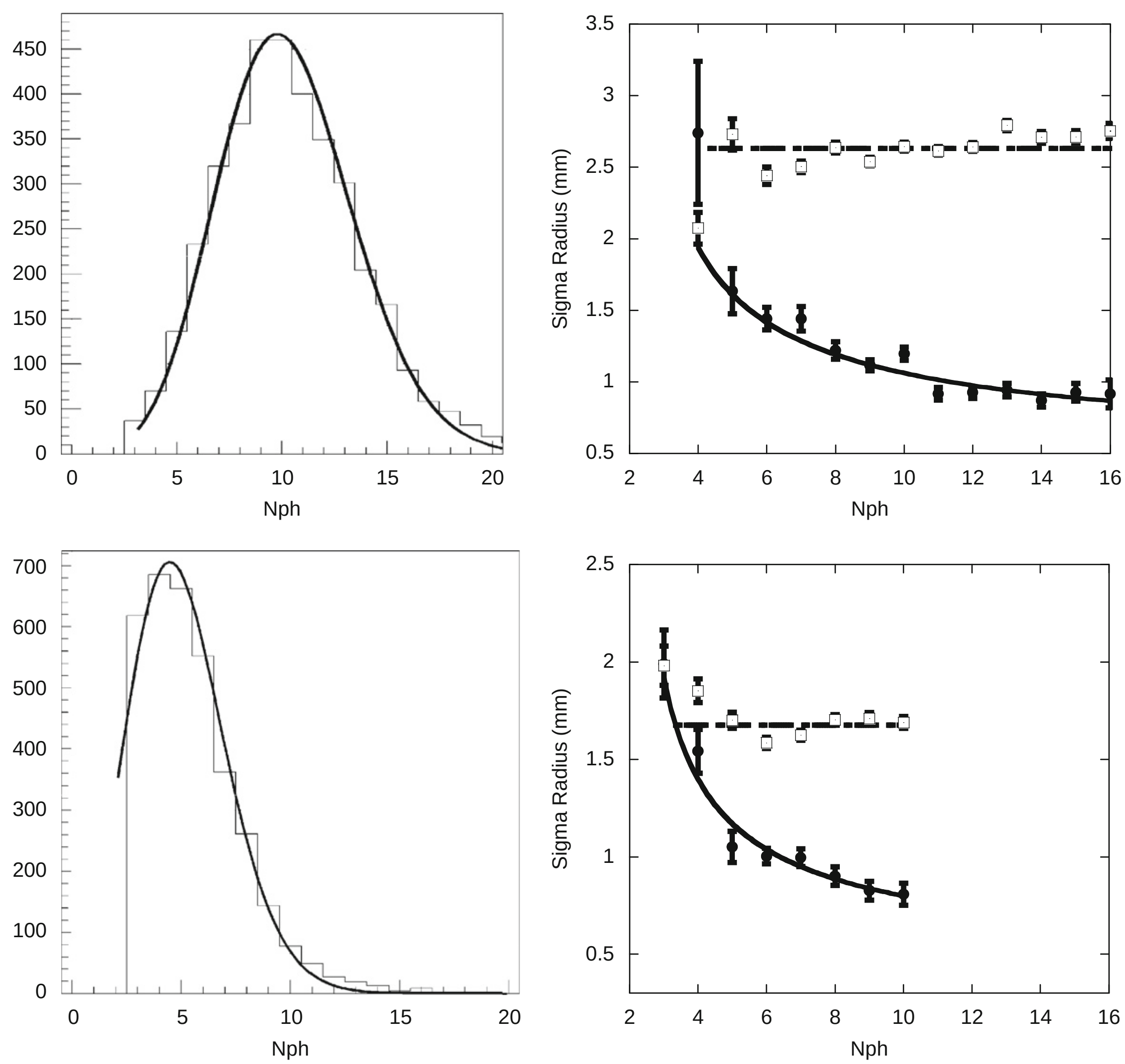

Fig. 4. Left panels: N_{pe} distribution produced in the multilayer aerogel (top part), and in a single layer (lower part). Right panels: the standard deviations of the Cherenkov radius ring from the multilayer (top part) and single layer (lower part) aerogel tiles, plotted versus the pe's detected in each ring, for all the pe's in a ring (full symbols) and for each single pe (empty symbols). The lines in the right panels are fits with Eq. (1).

serially on a single pin. The local FPGA, an ALTERA EP2C8F256 device, is devoted to handle the local bus in order to communicate with the Control Board (CB). It also handles the chip configuration procedure and the readout steps. In the readout phase, the FPGA performs a serial readout of the 64 fast digital signals from the chip and runs a trigger discrimination algorithm to enable the acquisition procedure. It can store temporarily in an internal memory both trigger information and channel values. The channel analog values are digitally converted using the 12 bit ADC chip AD7274. The FPGA can use an external trigger signal to strobe the data acquisition. The basic building block is a small Front-End card (FE) with a MAROC2 and an FPGA to configure the Front-End chip and to handle the readout modes. The FE cards communicate with the Control Board (CB), also FPGA-based, by means of the Backplane (BP) card, using a custom protocol which implements an event-driven readout. Among the CB tasks, it manages the USB 2.0 communication with a PC. By design the system can readout up to 4096 channels and sustains an event rate up to 25–30 kHz, with a 12 bit resolution in the A/D conversion. More details of the readout electronics can be found in Ref. [1].

In Fig. 1 the single photoelectron (pe) spectrum detected in one channel of a H9500 is shown. The standard deviation of the 1 pe peak divided by its distance from the pedestal is $\sim$30%. The right part of the pedestal peak shows a contribution that could be related to cross talk from adjacent channels or to pe's generated at the first dynode. In Fig. 2 the distribution of the pedestal peaks of eight H9500 channels is reported. A $\sim$1% (FWHM) uncertainty of the ADC chip AD7274 charge injected is observed. In Fig. 3 the distribution of the pedestal widths (FWHM) is reported, showing that $\sim 10-20\%$ of the MAPMT channels and associated electronics are noisy (FWHM values greater than $\sim$5 channels).

In the left part of Fig. 4 the distribution of the pe's produced by electrons in the multilayer aerogel (top part, average value $N_{pe}=10$) is compared with that (lower part, average value $N_{pe}=4.5$) from a single aerogel layer 9 mm thick. In the right part of Fig. 4 the uncertainties (standard deviations) in the measurement of the Cherenkov radius ring are reported for the two mentioned aerogel tiles and plotted against the pe number detected in a single ring, for all the pe in a ring (full symbols) and for the single pe (empty symbols). The lines in the right parts of Fig. 4 are relative to the fit of the uncertainties with the following equation:

$$\sigma_R = \sqrt{(\sigma_t/N_{pe})^2 + \sigma_p^2}. \tag{1}$$

A value $\sigma_p = 0.5$ mm has been obtained for the two aerogel studied. This value, higher than the dimension of the single photodetecting channel, includes a contribution from the electronics or general background. The σ_t values we obtained are: $\sigma_t = 1.5$ mm for the single layer and $\sigma_t = 2.0$ mm for the multilayer. These values, with a scaling factor with the aerogel thickness lower than the N_{pe}'s, suggest the validity of the use of a multilayer aerogel in a proximity focusing RICH detector.

3. Conclusion

The validity of a multilayer aerogel in reducing the uncertainty of the Cherenkov ring radius due to the radiator thickness has been proven in a proximity focusing RICH with a granularity of the photodetector plane as small as 9 mm^2. To cover a photodetector surface of 225 cm^2, eight MAPMTs have been used, each with 256 channels. For their readout, a custom made electronics, based on the MAROC2 chip, has been developed. New tests are foreseen on the electronics, to equalize the channel amplifications and to correctly evaluate the cross talk effect between adjacent channels for the H9500 MAPMTs, and on other multilayer aerogel tiles, one with four-layer in particular.

Acknowledgments

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Reference

[1] A.G. Argentieri, et al., A novel modular and flexible readout electronics for photon imaging applications, in: Nuclear Science Symposium Conference Record 2008 IEEE, vol. 1, 2008, pp. 2132–2136.