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Abstract

The CLEO detector has been upgraded to include a state of the art particle identification system, based on the Ring Imaging Cherenkov detector (RICH) technology, in order to take data at the upgraded CESR electron positron collider. The expected performance is reviewed as well as the preliminary results from an engineering run during the first few months of operation of the CLEO III detector.

1 Introduction

A crucial element of all the experiments exploring heavy flavour phenomenology is the particle identification system, with the primary goal of identifying π's, K's and p's. CLEO III is instrumented with a Ring Imaging Cherenkov detector (RICH) implemented in a barrel geometry comprising a total of 20 cm radial space between the tracking system and the CsI electromagnetic calorimeter.

Our goal is to achieve a π/K separation greater than 3σ up to the maximum momentum of particles produced in B meson decays at the $\Upsilon(4S)$,

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$\sim$ 2.65 GeV/c, the momentum characteristic of the very important decays $B \to \pi\pi/K\pi$. The π/K separation at this momentum is 14.3 mr. Thus the required angular resolution per track is $\sigma_t \leq 4.8$ mr. Our design parameters are a resolution per photon, σ_γ, of 14 mr and approximately 12 detected photons. This corresponds to $\sigma_t = 4.2$ mr. Note that we expect $\sim 2\sigma$ π/K separation from dE/dx information from the drift chamber enclosed in our system. Our Monte Carlo simulation, confirmed by an extensive set of test beam data [1], predicts that the CLEO RICH detector meets our goals. These expectations will be compared with preliminary data from an engineering run that took place during the first few months of detector operation.

2 Detector description

Figure 1 shows a $r - \phi$ section of the CLEO III RICH detector system. It involves an inner cylindrical shell comprising thin LiF crystal radiators [2], where charged particles moving with a speed greater than the speed of light in this medium produce the Cherenkov cone. Note that when the charged particle crosses the detector at normal incidence, the Cherenkov light is trapped inside the radiator because of total internal reflection. We have demonstrated [3] that this problem can be circumvented by shaping the outer surface of the radiator like the teeth of a saw, hence the name “sawtooth radiator”. The production of these radiators is more difficult because of the necessity of unconventional polishing techniques. Thus we are employing them only up to a dip angle of 22°.

The outer cylindrical shell of the detector is composed by thin gap multiwire chambers with their cathode plane finely segmented into 7.5×8 mm^2 pads, to reconstruct the location of the Cherenkov photons at the detector surface with high precision. The photosensitive element in these chambers is triethylamine (TEA), dispersed in CH_4. The sensitive bandwidth of CH_4-TEA is centered around 150 nm. Therefore we need to detect vacuum ultraviolet photons. Thus the interior faces of these chambers are made of CaF_2 windows, coated with metal strips that provide one of the two cathode planes. The use of CaF_2 windows and the need to seal tightly this system posed a great challenge to the mechanical design.

The cathode pad signals are processed by low noise front end electronics devices located at the back of the cathode planes. The fine segmentation needed involves a relatively complex readout system, featuring digitization and sparsification of 230,400 charge signals. A low noise ASIC called VA_RICH, custom made for this application by IDE AS, Norway, converts the charge induced in the cathode pad into a differential current signal. It features excellent noise performance, measured to be :

$$ENC(e^-) = 130 + 9 \times C_{in}(\mathrm{pF}) \tag{1}$$

This corresponds to an equivalent noise charge expected to be of the order of 250 e^- for the input capacitance seen by the preamplifier, dominated by the relatively long traces connecting the chamber pad to the chip input. The goal of keeping the electronic noise to a minimum is dictated by the single photon response, exponential in shape for the moderate gains at which we are planning to operate our chambers. This chip features also a high dynamic range, of the order of a few 100,000 electrons, in order to measure also the pulse height produced by the minimum ionizing particle, 20-50 times higher than the single photon pulse. The differential current signal is digitized and sparsifed in the data boards residing in VME crates located a few meters away from the detector. The challenge of maintaining the low noise performance in such a complex system is mitigated by the implementation of an online common mode subtraction prior to the sparsification process.

3 Preliminary performance characterization

The RICH detector was installed in CLEO in early August 1999 and the first data were collected starting in November 1999. The detector performance is very satisfactory. The transparency of the expansion volume is above 99% at 150 nm. The high voltage system is very stable and has been successfully operated at several different voltage settings. The average pad gain in the data reported here is $\sim 2.5 \times 10^4 e^-$. The electronics noise, prior to any working point optimization, has a mean value of 500 e^-, upon common mode subtraction, and of 750 e^- including the coherent component. This performance is quite remarkable for such a large system, powered by boards with a mixed digital and analog environment.

During the engineering run, the detector has been characterized in a “stand alone” mode, without resorting to any kind of external tracking information, not yet available. The data set used for this preliminary study is composed primarily of Bhabha events. For these events, having the simple topology of back to back charged tracks of opposite charge, we can reconstruct the track helix parameters using the centroid of the clusters corresponding to the e^+ and e^- intersection with the RICH pad chambers, combined with constraints determined by the event kinematics and the beam properties. We selected the large pulse heights to be charged track clusters. In addition we set their momentum equal to the beam energy and we assumed that the two tracks originated from a point with coordinates $x_0 = y_0 = 0$, exploiting the small transverse beam size, and $z_0 = (z_{e^+} + z_{e^-})/2$, where z is the coordinate along the beam direction.

Fig. 2 shows the Cherenkov angle distribution for single photons. These data are fit with a signal shape plus a polynomial background function. We find $\sigma_\gamma = 14.7 \pm 0.2$ mrad for flat radiators and $\sigma_\gamma = 12.2 \pm 0.4$ mrad for sawtooth radiators. These results are preliminary because the real tracking information from the combined silicon strip detector and drift chamber was not available. Moreover the RICH alignment is still underway. The number of detected photoelectrons is consistent with our expectations of about 12 γ's per track. Thus we can be confident that, once the tracking information is available and the alignment procedure is complete, we will achieve excellent particle separation at all the momenta of interest.

4 Conclusions

The first few months of operation of the CLEO III RICH have been quite successful. The detector has performed in a reliable manner and has proven to meet our specification. It will be a key element in the CLEO physics program in the next few years.

5 Acknowledgements

We would also like to thank T. Ypsilantis for the inspiring role that he had at the beginning of this work and for the great creative energy that he continues to bring to the field of particle identification.

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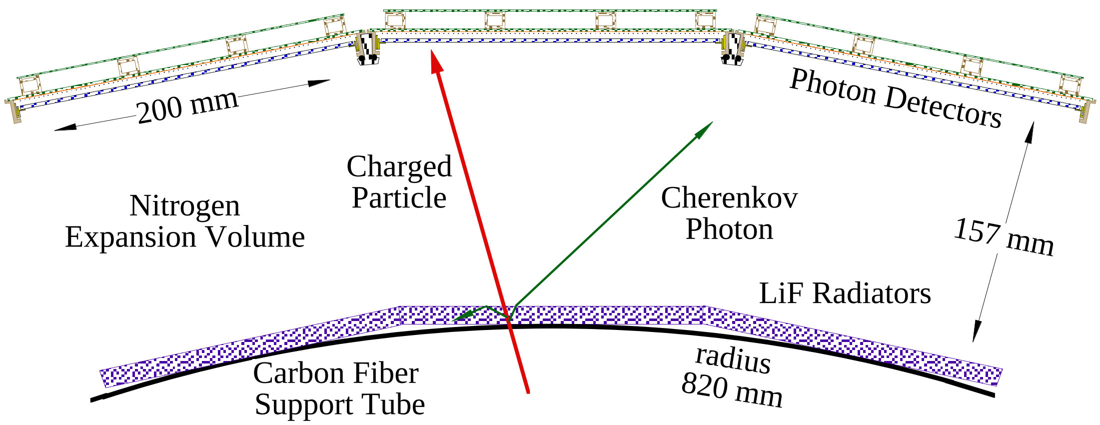

Fig. 1. $r - \phi$ section of one tenth of CLEO RICH detector as seen from the end.

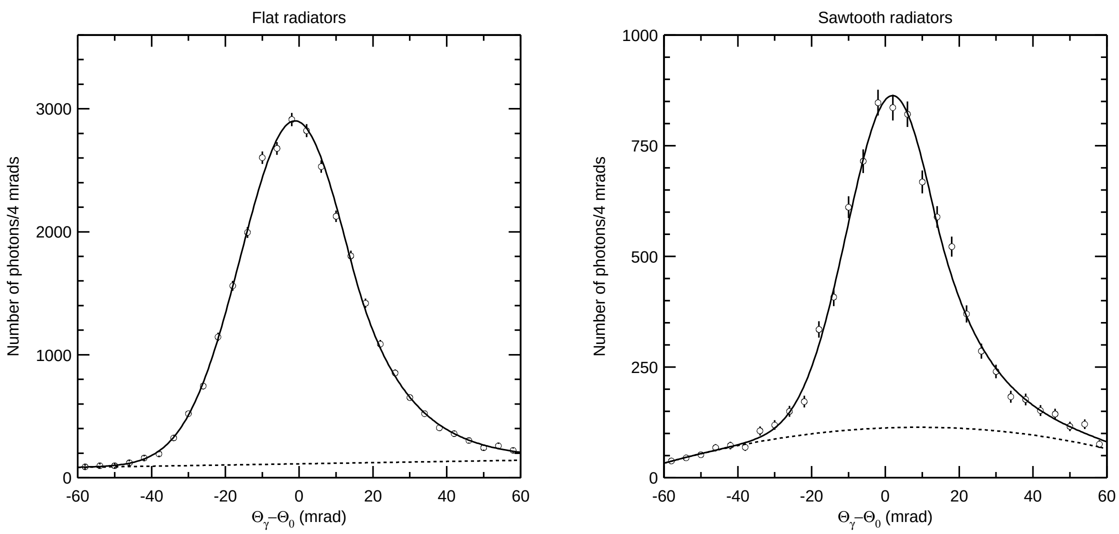

Fig. 2. Single photon Cherenkov angle distribution for plane radiator (left) and sawtooth radiator (right).