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RESULTS ON THE PERFORMANCE OF A BROAD BAND FOCUSSING CHERENKOV COUNTER*

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Abstract

The field of ring imaging (broad band differential) Cherenkov detectors[1] has become a very active area of interest in detector development at several high energy physics laboratories. Our group has previously reported[2] on a method of Cherenkov ring imaging for a counter with large momentum and angular acceptance using standard photo multipliers. Recently, we have applied this technique to the design of a set of Cherenkov counters for use in a particle search experiment at Fermi National Accelerator Laboratory (FNAL). This new detector operates over the range $0.998 < \beta < 1.000$ in velocity with a $\delta\beta \sim 2 \times 10^{-4}$. The acceptance in angle is ± 14 mrad in the horizontal and ± 28 mrad in the vertical. We report here on the performance of this counter.

Introduction

A standard technique for identifying hadrons at high energy is to measure their velocity with a Cherenkov counter and to use this result and a momentum measurement to determine the mass of the particle. A threshold Cherenkov counter produces an output signal for any particle whose velocity is greater than c/n, where c is the speed of light in vacuum and n is the index of refraction in the radiating medium. Threshold counters can be used to identify particles over a large angular acceptance, but they are unable to measure the velocity much above threshold. A counter of this type can typically distinguish kaons from protons over a range of a factor of two in momentum, and cannot separate kaons from pions at all in this range. Differential Cherenkov detectors, on the other hand, measure the angle at which the light is emitted, $\theta = \cos^{-1}(1/n\beta)$ where β is the particle's velocity divided by the speed of light. These counters focus the emitted Cherenkov radiation from a given charged particle to a circle in the focal plane of the light-collecting system. A narrow annular ring in the focal plane defines the narrow range of Cherenkov angles which may be detected by this counter. Only particles within a limited angular acceptance and within a fixed velocity range are detected. A counter of this type is often used to tag particles in beam lines, where the angular divergence of the beam is small and the momentum band is narrow.

In many experiments one needs a device which can measure the Cherenkov angle, as in the differential counter, but over a greater range of particle velocity and angle. The Cherenkov angle is determined by measuring the diameter of the ring of light in the focal plane of the detector. Recently counters using segmented photomultiplier arrays with high quantum efficiency (microchannel plates)[3] or photosensitive ionization detectors with good spatial resolution[4] have been proposed to accomplish these measurements, but several technical problems complicate their application. In this paper we describe a broad-band focussing Cherenkov counter which represents an intermediate step in this direction. A coarse measurement of the Cherenkov angle is made with modest improvements to the standard threshold device. The counter extends the velocity range of a threshold counter, while maintaining a reasonably large angular acceptance.

Principle

In a differential Cherenkov counter the light emitted by the particles is focussed to a ring of light in the focal plane. The radius of this ring is approximately $f\theta_c$ where f is the focal length of the focussing system and θ_c is the Cherenkov angle. The center of this ring will be displaced from the focal point of the optical system by an amount $f\theta_p$ where θ_p is the angle the particle's trajectory makes with the axis of the counter. In the conventional differential counter the angular band accepted by the slit must be less than the difference in Cherenkov angles between particle types, but larger than the angular dispersion of the particle beam.

The basic principle of our counter, which has been described previously in reference 2, is to divide the focal plane into two regions and to measure the amount of light falling into these areas separately. The boundary between these regions is shown in Figure 1. The rosette pattern was formed by evaporating aluminum onto a quartz substrate. Two 5" diameter photomultiplier tubes detected the light from these separate regions, one observing the reflected light and the other the transmitted light. The amounts of light in the two tubes provide an analog measurement of the Cherenkov angle from threshold to the maximum Cherenkov angle. The fraction of the light falling into each region is remarkably insensitive to displacements of the ring image from the axis of the light-collecting system.

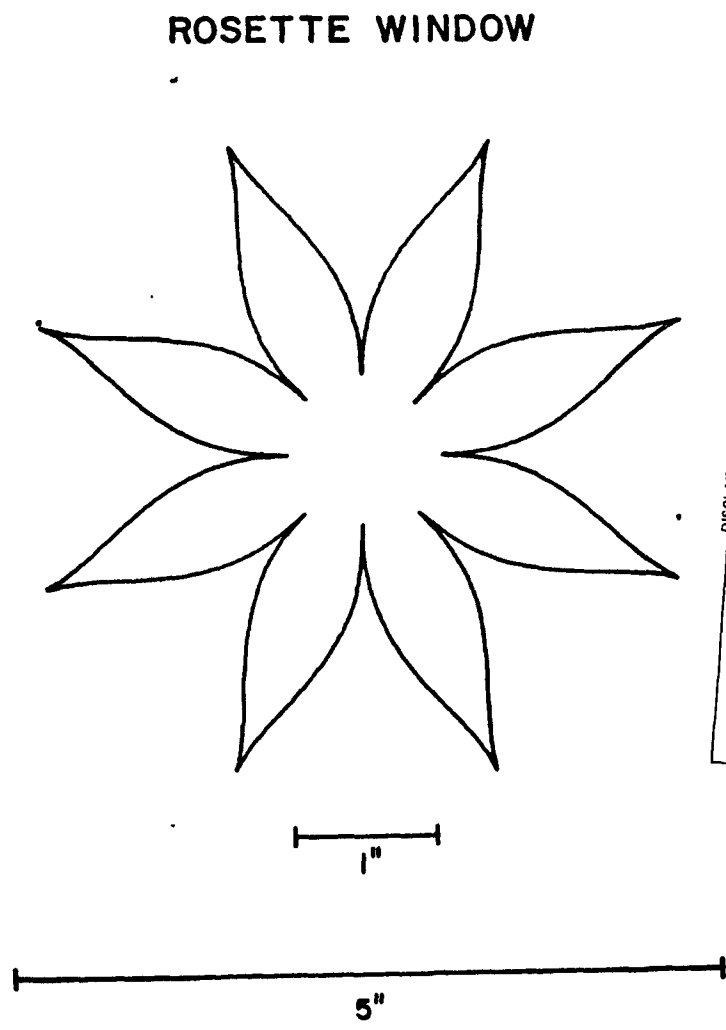

FIGURE 1. The outline of the reflecting mask which was placed on a quartz window in the focal plane of the Cherenkov counter.

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