THE HRS CERENKOV COUNTERS*

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Summary

We have successfully tested an ultraviolet photoionization Cerenkov Counter in a 10 GeV/c pion beam preparatory to building a large system to be installed in the HRS spectrometer. The counter has been tested to 11 atmospheres of pressure for use as a π/K separator.

Introduction

The separation of charged kaons from the more copiously produced pions adds significantly to the analyzing power of e^+e^- detectors. Time-of-flight techniques provide this separation up to about 1 GeV/c. However, at PEP and PETRA energies a large proportion of particles have momenta above this range. A useful device to tag kaons above 1 GeV/c would be a threshold Cerenkov counter. Due to the tight bunching of particles in jets, the counter must have high segmentation. Unfortunately the need to keep phototubes of a conventional counter outside a magnetic field makes a light guide system difficult if not impossible to design. For this reason Cerenkov counters which use proportional chambers to detect the ultraviolet part of the spectrum (1150 - 1350 Å) have been developed.[1-3] The proportional chambers are doped with a small amount of benzene. Benzene is chosen because it has a high photoionization probability in this wavelength range.

This paper describes tests of a prototype cell of the ultraviolet threshold Cerenkov counter system which is to be installed in the High Resolution Spectrometer (HRS), a PEP detector. The counter will consist of 13 individual tori placed around the beam as shown in Fig. 1. The design allows for high segmentation (64 cells per torus) while the amount of material contributing to multiple Coulomb scattering is minimized. Each torus is constructed of 8 flanged units which bolt together to form a polygon of 16 segments. A group of 4 proportional chambers share a common planar — elliptical mirror. The Cerenkov radiator will be an argon/nitrogen mixture at 16 atmospheres pressure. This gives a π threshold at 1.1 GeV/c and will allow π/K separation from 1.1 to 3.9 GeV/c. In addition, time-of-flight counters give a one standard deviation separation of π's and K's up to 1.3 GeV/c.

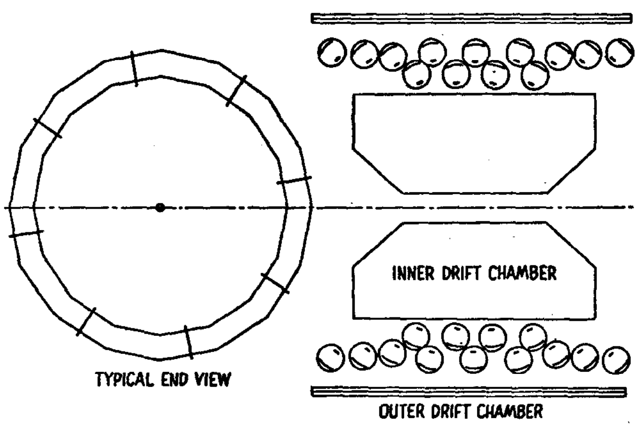

Fig. 1. End and side view of the planned Cerenkov counter system for the HRS.

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Principle of Operation

The principle of the photoionization Cerenkov counter is much the same as that of a conventional gas threshold Cerenkov counter. The particle traverses and radiates photons in a gas, the number of photons per unit length of the radiator is given by

$$\frac{d\varphi}{d\ell} = 370\int \varepsilon \sin^2\theta \, dE$$

where ℓ is the particle path length in cm, θ is the Cerenkov angle, E is the photon energy in electron volts and ε is the photon detection efficiency. ε is dependent on the U-V transmission of the proportional chamber window (typically 45% for magnesium fluoride) and the mirror reflectance (typicably 75%), both of which vary with photon energy.[2] The wavelength window is defined by the photoionization efficiency of benzene which is zero above 1350 Å and approximately 50% down to 1160 Å. CO_2, which is used as a quenching gas in proportional chambers, is absorbing below 1160 Å. Also a radiator gas must be chosen which is transparent or absorbs U-V photons only weakly.

The choice of Cerenkov radiator was a 85% argon, 15% nitrogen mixture. Argon is known to be transparent in the wavelength range of interest.[2] The nitrogen was added to quench scintillation light. Argon and nitrogen have similar refractive indices at these wavelengths; however nitrogen is known to absorb ultraviolet photons weakly.[4] Although the absorption length of nitrogen is large (187 cm) absorption becomes significant in a pressurized system. Xenon and krypton are known to transmit UV[3] and have higher refractive indices than argon, however the photon yields would be inadequate for the proposed HRS detectors.

Neglecting the effects of dispersion, the number of photons per unit length can be simplified to

$$\frac{d\varphi}{d\ell} = \text{No} \sin^2\theta$$

where No is a constant dependent on the parameters described above. An estimation of these parameters yields an expected value of 70 for No.[2]

Experimental Setup

A prototype of the cell geometry to be used in the HRS was built. This geometry is shown in Fig. 2. The test section consisted of a 25.4 cm diameter aluminum tube of 0.32 cm thickness (1/8th of a complete torus). Contained inside the tube was a 22.9 cm wide cylindrical mirror with a elliptical cross section. The proportional chamber was placed 15 cm from the mirror at its first focus. The second focus would correspond to the e^+e^- intersection point, 200 cm away.

The structure of the proportional chamber is shown in Fig. 3. The design has gone through a variety of stages.[3] The chamber was 15.2 cm long and contained six cells, each 0.5 cm wide. The dead region between cells was 0.5 mm. A 2 mm thick MgF_2 window was sealed to the proportional chamber with an O-ring. Each cell contained a sense wire (38 microns diameter gold-plated tungsten) which was positioned 2.4 mm from the window. The six cell structure was chosen for two reasons. The proportional chamber runs at atmospheric pressure and therefore must support the MgF_2 window. Also the chamber presents a dead region since if a particle goes through the proportional chamber it will fire regardless of

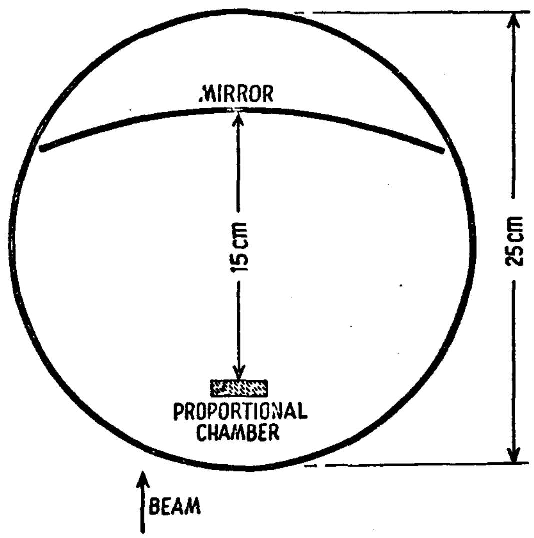

Fig. 2. Cross-sectional view of the Cerenkov counter test vessel.

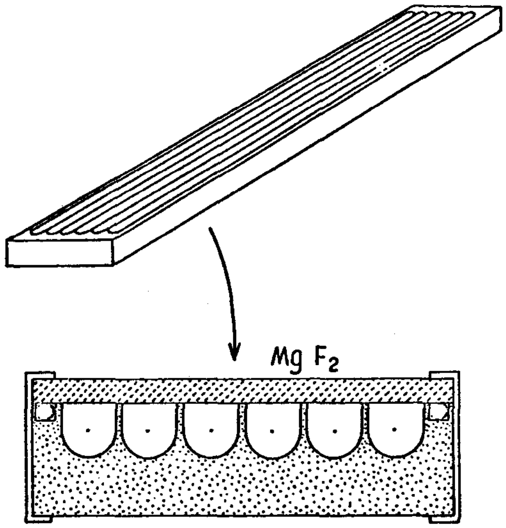

Fig. 3. Structure of the proportional chamber.

whether the particle was above threshold or not. If the chamber has discrete cells, 5/6 of the chamber is still active for Cerenkov light when a cell is struck. However, to reduce electronic read-out costs, pairs of cells are grouped together.

The preamplifier is a crucial element in the system. It must have low noise to detect single photoelectron avalanches efficiently. Each proportional chamber cell pair fed a separately housed low noise FET charge to voltage preamplifier with an 800 ns output time constant. Since linearity is not required the preamp can be of very simple design. The preamplifier output was firstly RC coupled to a discriminator of adjustable threshold via an external amplifier and secondly to an ADC channel with composite sensitivity 96 counts/femto-Coulomb. In this case the readout electronics operated at a signal to noise of 4/1 for signals above 0.3 femto-Coulomb.

The mirror reflectivity has been measured to be 75% at 1216 Å. The mirror was made of glass, 2 mm thick. It was slumped on a graphite form which had the desired elliptical curvature. The glass was then vacuum aluminized with a MgF_2 overcoating to prevent oxidation.[6]

The mirrors were chosen to give one dimensional focusing in the elliptical plane. This means there is no focusing in the direction of the magnetic field bend. Because the counters form a complete azimuthal ring (see Fig. 1) this does not lead to an efficiency loss.

Preliminary Tests

The addition of benzene as a photoionizing chemical tends to destabilize the proportional chamber. When a proportional avalanche occurs many argon atoms are excited. The argon emission spectrum is centered around 1000 Å. These photons can photoionize the benzene causing further avalanches. A suitable quenching agent must absorb these photons while transmitting UV light in the 1150 to 1350 Å region. CO_2 has a short absoprtion length below 1160 Å and a "window" at the desired wavelengths.[5] We experimented with a number of gas mixtures — argon with 1% C_6H_6 and 5%, 10%, 20%, and 30% CO_2. We found that more CO_2 is needed than for a standard proportional chamber, a useful mixture being 1% benzene, 20% CO_2 and 79% argon. It was found that 30% CO_2 raised the operating voltage by 100 volts but did not affect the chamber stability or improve the single photon detection efficiency. The 1 mole percent benzene was chosen so that there are several mean absorption lengths for the UV photons in the chamber.

An interesting feature of the proportional chamber was its ability to detect visible photons as evidenced by its sensitivity to an overhead room light. We attributed this to the photoelectric effect off the aluminum oxide layer on the chamber walls. Silvering the proportional chamber surface eliminated the effect.

One worry was that the proportional avalanches would affect window transmission. The transmission of the MgF_2 window was measured to be 50% using a Lyman alpha (1216 Å) hydrogen discharge lamp. The chamber was run for 10^{10} counts just below breakdown and the MgF_2 transmission was remeasured. No noticeable difference was observed indicating that breakdown products formed by counter avalanches do not degrade the window transmission.

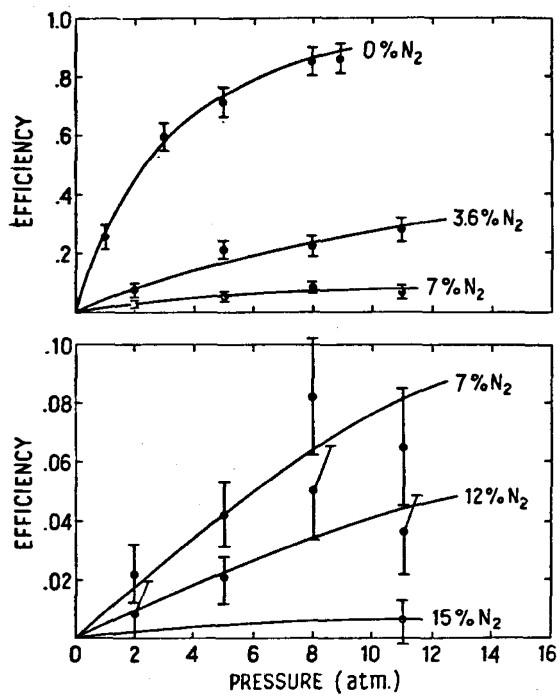

Fig. 4. Efficiency for detecting scintillation light as a function of pressure and nitrogen percentage.

Scintillation light can be produced by a particle below its Cerenkov threshold thus destroying the usefulness of the counter for particle identification. Tests were made[3] to determine the scintillation properties of argon-nitrogen mixtures as a function of nitrogen percentage and pressure. The results are shown in Fig. 4 where the efficiency for detecting scintillation light as a function of argon gas pressure is plotted for various fractions of nitrogen. It can be seen that an 85% argon, 15% nitrogen mixture keeps the scintillation light level below 1%. We consider this fraction to be the optimum mixture, the addition of more nitrogen will cause the unnecessary absorption of Cerenkov photons.

Results

The Cerenkov counter was initially tested with the discriminator electronics in a 10 GeV/c negative pion beam at SLAC. The threshold behavior of the counter is shown in Fig. 5. Here the efficiency is shown as a function of Cerenkov gas pressure for a 90% argon — 10% nitrogen and a 100% nitrogen radiator. The efficiency rises to 98.4% for the 90% argon — 10% nitrogen mixture. The small inefficiency is consistent with the antiproton contamination in the beam. Unfortunately there was no low energy beam available at SLAC with which to measure the momentum dependence. The effect of nitrogen absorption is clear. If the nitrogen curve is corrected for absorption in order to agree with the argon curve, the resulting value obtained for the absorption length is within 10% of the published value.[4] The argon/nitrogen gas used both had purities of 99.999% which was sufficient to make absorption by gas impurities unimportant. The solid curve in Fig. 5 is a fit to the data and shows the efficiency expected for No = 43.5 based on Poisson statistics.

The counter was further tested in a 10 GeV/c e^+ beam using the previously described low-noise preamplifier and ADC. The performance of the test vessel was evaluated by calculating No (from the Cerenkov efficiency) for a series of ADC pulse height cuts at a constant pressure of 3 atmospheres absolute. The results are shown in Fig. 6. Here No is plotted as a function of ADC channel cut. The ADC pulse height spectrum is shown in Fig. 7. ADC channel 70 is 4 standard derivations from the mean of the widened pedestal and represents an observed No of 65 (see Fig. 6). Using this value of No we can deduce the efficiency of a 16 atmosphere system proposed for the HRS. Taking into account bending in the magnetic field, finite beam crossing

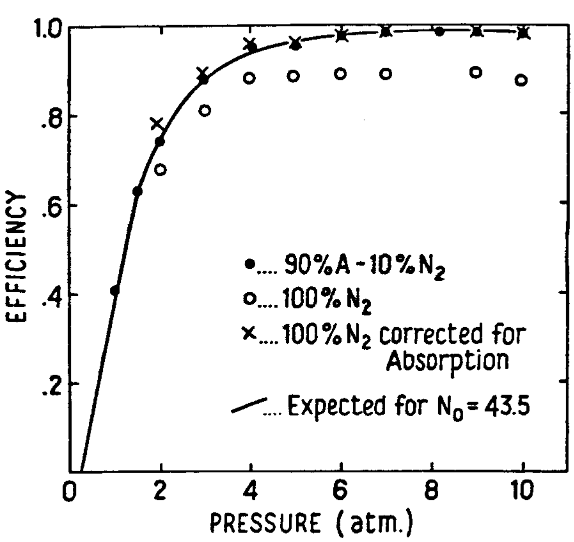

Fig. 5. Efficiency of the counter as a function of pressure for various gas mixtures.

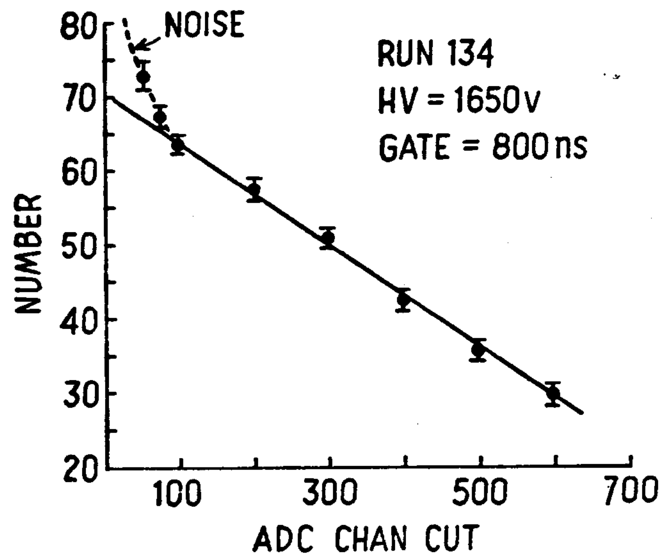

Fig. 6. The measured value of No as a function of ADC channel cut.

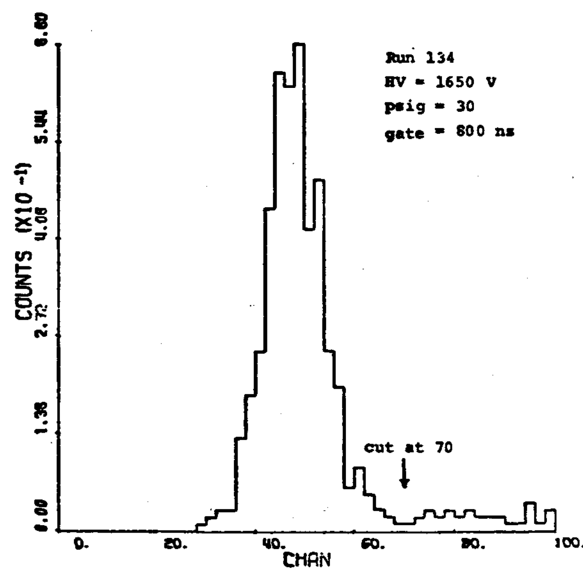

Fig. 7. The ADC pulse height spectrum showing the pedestal representing preamplifier noise.

size, etc. and incorporating the geometry of Fig. 1, the efficiency as a function of momentum was evaluated using Monte Carlo techniques. The results of this study are shown in Fig. 8.

The first torus was installed in the HRS detector during the summer of 1981 and collected data during the fall. Construction of the remaining tori and electronics is to proceed through the spring of 1982 with plans to install the complete system during the summer.

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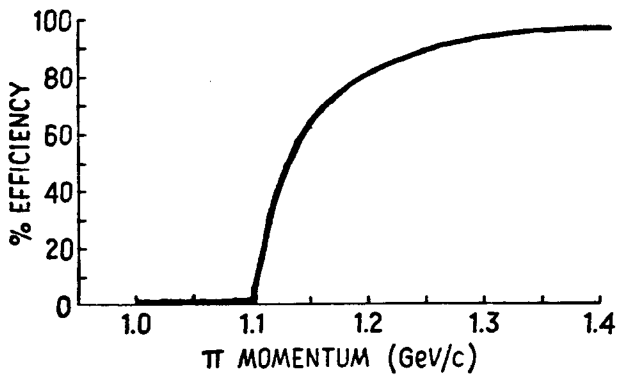

Fig. 8. Expected efficiency of a system of counters as a function of π momentum.

References

1. J. Seguinot and T. Ypsilantis, NIM 142, 377 (1977).
2. J. Chapman, D. Meyer and R. Thun, NIM 158, 387 (1979).
3. N. Harnew and D. Meyer, NIM 186, 513 (1981).
4. Y. Tomkiewicz and E. Garwin, NIM 114, 413 (1974).
5. E. C. Y. Inn et al., J. Chem. Phys. 21, 1648 (1953).
6. G. Hass and R. Tousey, J. Opt. Soc. 49, 593 (1959).