Hadron Identification from 1 to 16 GeV/c

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ABSTRACT

We present a short review of the hadron identification devices in the 1-16 GeV/c momentum range pointing out their separation capabilities. Two implementations will be discussed in some details: the first RICH with an aerogel radiator and a compact RICH with CsI photon converter.

1 Introduction

The (sub)nuclear physics investigation performed at Jefferson Lab through electron scattering will gain considerably when improving the identification of π, K and p.

With the present experimental setup a 'clean' separation in Hall A and C is possible only between p and π; identification of K is challenging and only possible in a restricted kinematical range. The approved experimental program on keon physics would benefits from a better hadron identification system.

With the foreseen higher energy upgrades the hadron identification will be more critical and the construction of new equipments mandatory.

Table 1: Rough estimation of the hadron relative pupulations in electron scattering on light nuclei.

Momentum	π/p	π/K
< 5 GeV/c	~ 1	$\sim 10^3$
> 5 GeV/c	~ 10	$\sim 10^4$

2 Contamination

Among the different aspects of hadron identification we will concentrate in this short paper on one of the most important: the contamination C, that is the fraction of misidentified particles over the total particles assigned to a specific type.

C is strongly related to the relative particle population and to the PID system resolution[1] σ_{PID}: the contamination is inversely proportional to the particle abundance. Table 1 presents a very rough estimation of the expected relative

[1] The PID resolution can be defined as the variance of the gaussian-like distribution of a particle type respect to the relevant variable of the PID system.

The contamination can be lowered combining different 'overlapping' PID systems and/or PID selections on missing mass, coincidence time, etc.

$C \sim$ few % is the minimum requirement for most of the applications; this correspons to $n_\sigma \sim 4.7$ for particles with equal populations; since K and p are usually less abundant than π, their clean indentification requires stronger conditions on n_σ.

The PID efficiency, which include the 'hardware' detector efficiency and the software/analysis cut efficiencies, represents another important parameter in every detector system: the contamination can be reduced sacrificing the efficiency.

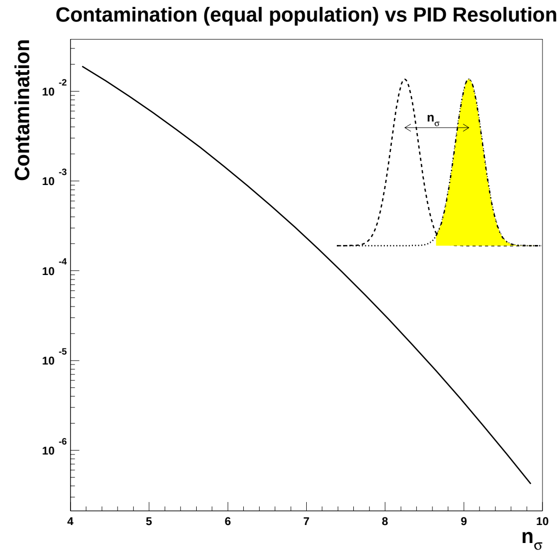


Figure 1: The contamination of particles with equal abundance versus the separation (in unit of σ_{PID}) between the two gaussian-like particle distributions (along the relevant PID variable). To obtain the contamination for a particle with P pupulation, you must multiply the contamination values by P.

3 TOF

Time of Flight helps hadron identification in the low momentum region (below a few GeV/c); time resolution is the relevant parameter which affects the identification capability.

With an effective hodoscope segmentation, a sharp beam crossing time and a very good PMT time resolution it is possible to have an overall PID resolution of $\sigma_{TOF} \sim 250$ ps.

As figure 2 shows, the $\pi - K$ separation (the most critical), at $5\sigma_{TOF}$ can be performed optimistically up to 2 GeV/c. In the following we will illustrate the proximity focusing RICH detector which allows a cleaner and extended separation.

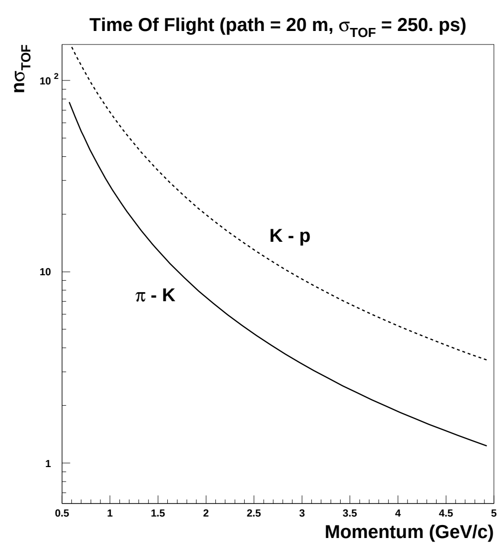


Figure 2: Time of Flight difference in a 20 m path, as could be optimistically done in Hall A.

4 Threshold Čerenkov

The threshold Čerenkov counters are the most used hadron identification detectors; their relevant parameter is the mean number of detected photons (photoelecrons) N_{pe} emitted by a charge particle above the threshold momentum. The plot of fig. 1 cannot be applied to this case since one of the two distribution is not gaussian-like due to the threshold nature of the effect.

several counters with different radiators are required.

Note that the aerogel radiator is needed, below 4 GeV/c, to avoid the use of high pressure gases.

5 RICH

The most effective hadron identification device is the sophysticated RICH detector [1].

Critical parameters are here N_{pe}[2] and the angle uncertainty; the latter is affected mainly by the spatial resolution of the photon detector and by the optical characteristics of the radiator. The former depends strongly on the quantum efficiency of the photon detector and again on the radiator optical characteristics.

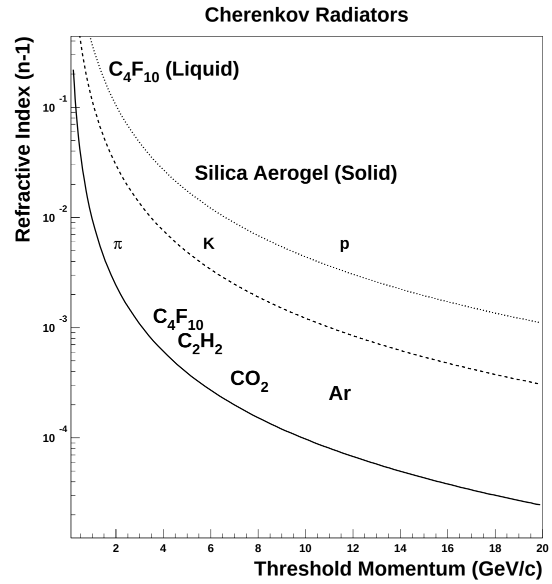


Figure 3: Refractive index versus threshold momentum of π, K and p. Working regions of some Čerenkov radiators are shown.

5.1 HERMES RICH

Last two years we have been involved in the project of the HERMES RICH [2], which uses for the first time the silica aerogel as radiator. The schematic view of the detector is shown in figure 4 where its main components are also described.

This detector has been installed in the HERMES spectrometer in the East-Hall of the HERA e-p collider (DESY - Hamburg) in Spring 1998.

From the Montecarlo simulation and the prototype tests, the HERMES RICH should be able to fully identify hadron between about 1.5 GeV/c up to 16 GeV/c with a contamination[3] well below 10% at an overall efficiency above 95% [3] (first results in Fall 1998).

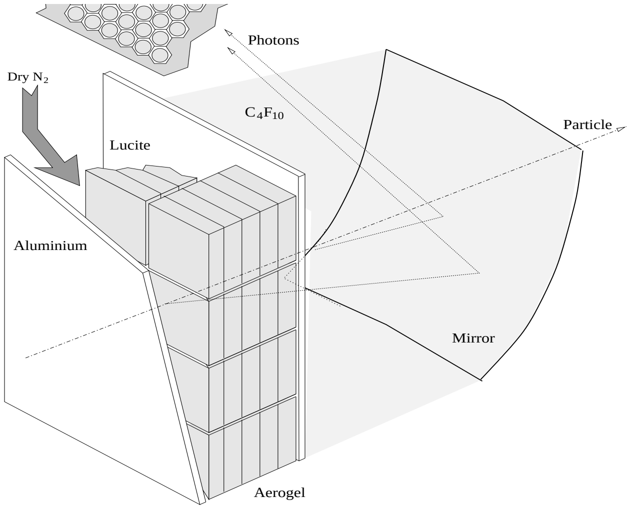
The HERMES RICH geometry could fit quite well in a possible future upgrade of the Hall A/C spectrometers; its identification capability can be updated (with considerable financial effort) changing its photon detector system based now on standard 3/4" PMT with a multianode PMT or HPD system which will have a much higher spatial resolution. The gain in term of n_σ will be of about one order of magnitude.

5.2 Proximity focusing RICH

The ALICE HMPID RICH group had developed a proximity focusing RICH [4] made of a freon (C_6F_{14}) liquid radiator and a CsI photosensitive film evaporated

[2] Here N_{pe} represents the mean number of detected photons which can give information on their emission angle; contrary to the threshold Čerenkov counter, the scattered photons are hence excluded being noise for the RICH.

[3] The hadron relative populations in HERMES are close to those of table 1.



HERMES RICH characteristics	
APPROX. SIZE	200 cm^3
GAS (C_4F_{10})	$n = 1.0014$
AEROGEL	$n = 1.03$
SPH. MIRROR	$R = 220$ cm
PH. DETECTOR	1936 PMTs exagonal array
PMT	3/4", +HV, low corrent
READOUT	binary

Figure 4: Schematic view of the HERMES RICH detector.

on the pads of a 2D position detector. A schematic view of the RICH is shown in figure 5.

Such a detector has been proved to be suitable for the hadron identification up to about 4 GeV/c with a separation capability $n_\sigma > 5$, being $n_\sigma(\pi - K) \sim 20$ at 2 GeV/c.

Its low cost and compacteness make it one of the best solution for the Hall A/C full hadron identification system at the present beam energies. Its use in Hall A is currently under investigation.

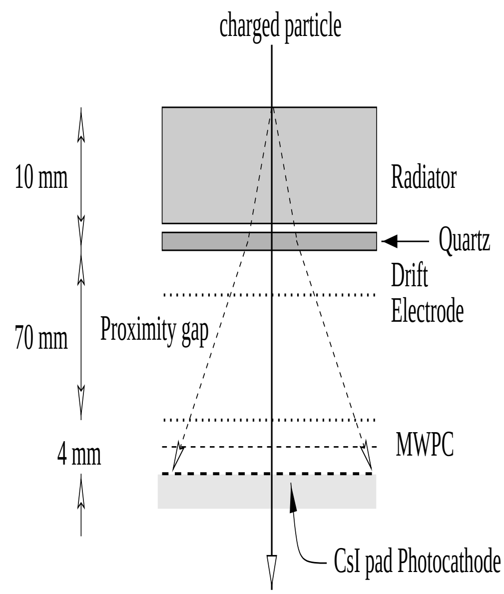


Figure 5: Scheme of a proximity focusing RICH.

References

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[2] E. Cisbani et al., *Proposal for a dual radiator RICH for HERMES*, (HERMES internal note 97-005, January 1997).

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