Recognition of Cherenkov ring patterns with the HMPID-RICH detector in ALICE at LHC

The ALICE-HMPID Group

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A high momentum particle identification detector (HMPID) covering about 5% of the ALICE central barrel region has been designed and prototyped.

The detector consists of seven RICH modules with a proximity focusing geometry, covering 12 m^2. The very large density of hits on the detector ($80 \div 90$ part/m^2 in the extreme cases) makes the recognition of the Cherenkov photon patterns a complex and crucial task. A study of the pattern recognition strategy based on the Hough transformation in terms of particle identification efficiency and particle contamination will be presented.

1. The CsI-RICH detector

The technical details of the detector layout have been presented in previous papers[1–3]. Here a short description of the basic principle of functioning is reported. When a charged particle moves through the RICH (fig.1), Cherenkov photons are emitted in the radiator consisting of a 10 mm thick layer of C_6F_{14} liquid. The C_6F_{14} refractive index (n=1.29 at 170 nm) determines the momentum threshold $p_{th} \simeq 1.26 \times m$ GeV/c, where m is the mass of the charged particle in GeV/c^2. The UV photons are detected by the photodetector, consisting of a conventional MWPC with anode wires of 20 μm diameter, 4 mm pitch and 2 mm anode-cathode gap. Photons convert into electrons on a solid photocathode consisting of a thin layer of CsI evaporated onto a plane segmented with pads of 8×8 mm^2.

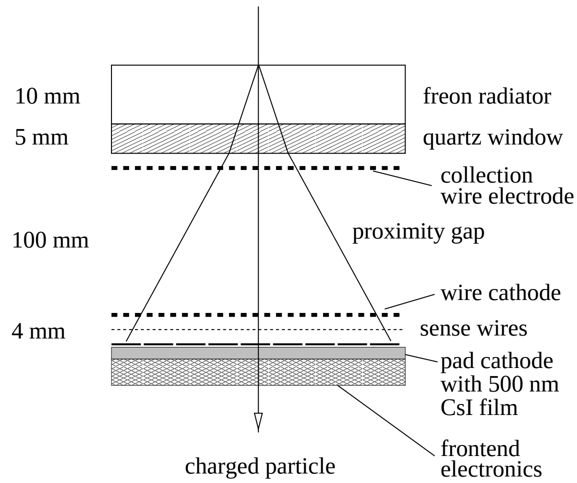

Figure 1. Schematic view of the HMPID CsI-RICH.

The space ("proximity gap") between the radiator and the MWPC improves the angular resolution of the measured Cherenkov angle by ensuring the most convenient size of Cherenkov ring images on the photocathode plane with respect to the chromaticity of the radiator and the spatial resolution of the photon detector. The collection wire electrode placed in the proximity gap, near the quartz window, prevents the electrons created by ionizing particles to enter the MWPC sensitive volume. The analog pad readout allows an accurate photoelectron localization by means of the reconstruction of cluster centroids.

2. Pattern recognition with RICH in ALICE

The efficient recognition of circular (or elliptical) patterns plays a crucial role in the analysis of high particle density events, anticipated in central Pb-Pb collisions in ALICE (dN/dy$\sim$5000$\div$8000). The algorithm for the recognition of Cherenkov patterns used in this analysis is based on the Hough Transform Method (HTM). The method, based on the conformal transformation of the pad coordinate space directly to the Cherenkov angle parameter space, presents the advantage to work regardless of the pattern shape and/or noise contributions. For more details see ref.[4].

The performance of the method has been evaluated on events generated with the detector simulation code GALICE[5]. One central Pb-Pb event ($\sim$13% of pad occupancy) has been fully simulated in the ALICE setup by generating the primary and secondary particle flux with the HIJING event generator (fig.2). The contribution of neutrons has been simulated with FLUKA[6].

In order to study a particular set of ring patterns at fixed momentum and incidence angle in the ALICE multiplicity environment, one ring at the time has been generated and superimposed to the Pb-Pb event.

Pions, kaons and protons of different momentum impinging the central HMPID module[2] at normal incidence have thus been analyzed. Fig.3 shows the distributions of the reconstructed η_c Cherenkov angle for π, K and p at two different momenta.

The performance of the pattern recognition method has been studied in term of particle identification efficiency and particle contamination. If N_i^{found} is the number of the recon-

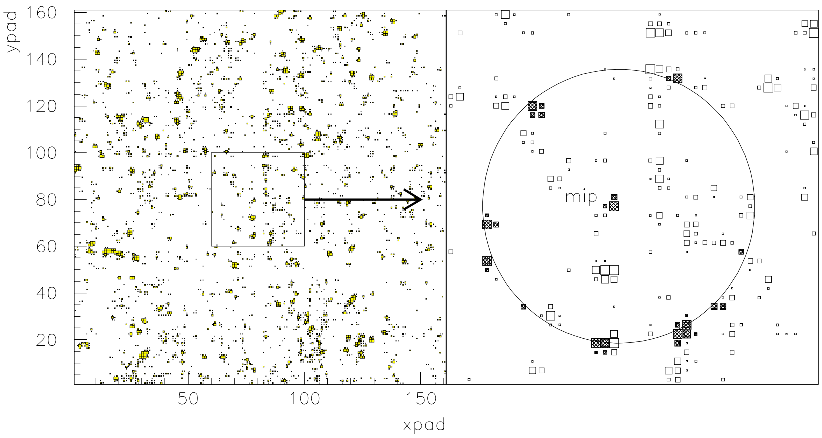

Figure 2. Left: hit map of central HMPID module in ALICE generated with the GALICE package for one Pb-Pb central event (dN/dy=8000). Right: a detail of the previous hit map showing the region where the generated ring has been merged to the event (the ring pads are in black). The reconstructed Cherenkov ring is also shown.

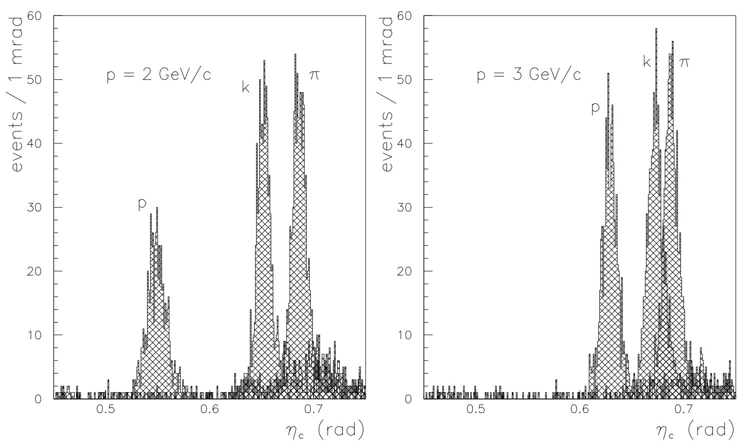

Figure 3. Distributions of reconstructed Cherenkov angle η_c for 1000 of π, K and p at two different momenta.

structed rings with η_c in a selected range for a given particle, while N_i^{tot} is the number of the total simulated rings in the same η_c range, then the efficiency Eff_i and contamination Cont_i are defined as follows:

$$\mathrm{Eff}_i = \frac{N_i^{found}}{N_i^{tot}} \;;\; \mathrm{Cont}_i = \frac{N_j^{found}+N_k^{found}}{N_i^{found}+N_j^{found}+N_k^{found}} \qquad i{\neq}j{\neq}k \quad (i=\pi,K,p)$$

where the expected particle production ratios, estimated with HIJING, have been applied to calculate Cont_i (see fig.4).

The choice of the η_c interval in which Eff_i and Cont_i have been evaluated is a result of a compromise between a good efficiency and a low contamination, depending on the physics signal under study.

Table 1 shows the efficiencies and contaminations evaluated for π, K and p in the momentum range 2÷3 GeV/c. The calculations have been performed implanting full rings

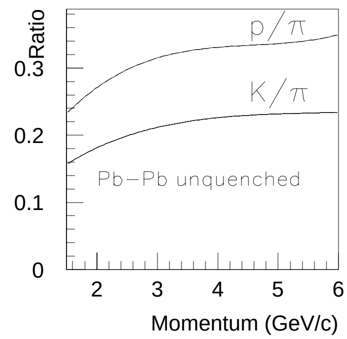

Figure 4. Expected yields (not including jet quenching) in central Pb-Pb events in ALICE.

in a very high density particle event (dN/dy=8000), and lower density (dN/dy=5400), with two different proximity gap sizes, corresponding to R=122 mm and R=155 mm ring radii at normal incidence. We clearly observe a strong decrease of the contamination with the density, and also an evident preference for the smaller ring radii. The efficiency for protons of ∼50% at low momenta (near to the momentum threshold) is due to the low number of emitted photons, making the pattern recognition difficult.

The choice of the η_c interval to compute the efficiency and the contamination is, however, related to the physics signal under study with the HMPID. As an example, the contamination of 20% for charged kaons, with an efficiency of 50%, is still acceptable for studying the KK pair correlation with a low background[7].

Table 1. Efficiency and contamination for π, K and p in the momentum range 2÷3 GeV/c. Events with Cherenkov patterns fully contained in the pad plane have been considered.

$p = 2$ GeV/c	π	K	p
eff. (%)	80	60	52
cont. high dens. R=155mm(%)	5.1	13.0	6.6
cont. low dens. R=155mm(%)	2.0	4.7	2.4
cont. high dens. R=122mm(%)	2.3	7.2	1.5
$p = 2.5$ GeV/c	π	K	p
eff. (%)	80	40	67
cont. high dens. R=155mm(%)	6.5	17.7	4.6
cont. low dens. R=155mm(%)	2.6	9.0	0.9
cont. high dens. R=122mm(%)	3.2	12.8	2.5
$p = 3$ GeV/c	π	K	p
eff. (%)	80	37	74
cont. high dens. R=155mm(%)	8.2	25.0	6.1
cont. low dens. R=155mm(%)	3.3	14.0	1.6
cont. high dens. R=122mm(%)	5.0	23.0	1.8

The efficiency and contamination when circular patterns are partially outside the RICH plane have also been computed. The results are shown in fig.5. The efficiency for π, K and p decreases of about 15÷20% and the contamination increase of about a factor 1.5÷2.

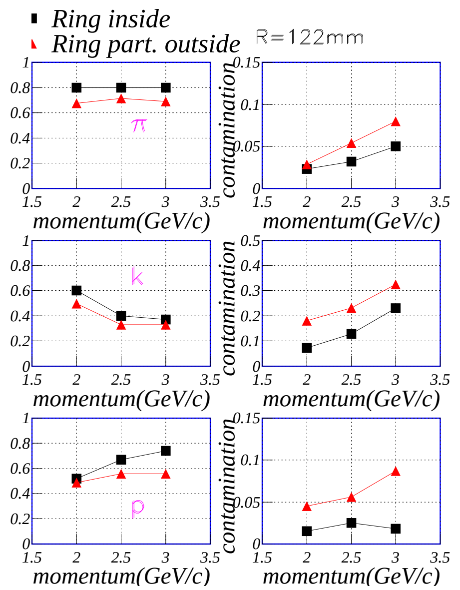

Figure 5. Efficiency and contamination for rings fully contained (squares) and partially contained (triangles) in the HMPID photocathode plane.

3. Conclusion

The performance of the recognition strategy of circular Cherenkov patterns based on the Hough transformation, in a fully simulated central Pb-Pb ALICE event (dN/dy=8000), has been studied in terms of particle identification efficiency and particle contamination.

An efficiency of 80% and a contamination of about 3.5% has been achieved for pions in the interval 2≤p≤3 GeV/c, at normal track incidence to the detector plane and with the ring fully accepted by the detector, while an efficiency from 60% to 40% and a contamination from 7% to 23% has been evaluated for kaons. The efficiency for protons increases from 52% to 74% and remains nearly 80% above 3 GeV/c, with a contamination of about 2%. In addition, when the ring is partially accepted by the detector, the efficiency decreases of 15÷20% and the contamination increase of a factor 1.5÷2 for π, K and p.

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