Very high Momentum Particle Identification detector for ALICE at the LHC

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Abstract. The anomalies observed at RHIC for the baryon - meson ratios have prompted a number of theoretical works on the nature of the hadrochemistry in the hadronisation stage of the pp collisions and in the evolution of the dense system formed in heavy ion collisions. Although the predictions differ in the theoretical approach, generally a substantial increase in the baryon production is predicted in the range 10-30 GeV/c. This raises the problem of baryon identification to much higher momenta than originally planned in the LHC experiments. After a review of the present status of theoretical predictions we will present the possibilities of a gas ring imaging Cherenkov detector of limited acceptance which would be able to identify track-by-track protons until 26 GeV/c. The physics capabilities of such a detector in conjunction with the ALICE experiment will be contemplated as well as the triggering options to enrich the sample of interesting events with a dedicated trigger or/and using the ALICE Electromagnetic Calorimeter. The use of the electromagnetic calorimeter opens interesting possibility to distinguish quark and gluon jets in gamma - jet events and subsequently the study of the probability of fragmentation in proton, kaon and pion or triggering on jets in the EMCAL. Such a detector would be identify pions until 14 GeV/c kaons from 9 till 14 GeV/c and protons from 18 till 24 GeV/c in a positive way and by absence of signal from 9-18 GeV/c.

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In the existing space in the ALICE detector and the physics requirement the only possibility is to use gas a Cherenkov counter as the choice detector. Therefore we review here shortly the main elements of the considered Cherenkov detector: the choice of radiator gas, the photon detection and the geometry of the detector.

Gas with low index of refraction that qualify as radiators are fluorocarbons gas like CF_4 ($< n > \approx 1.0005$, $\gamma_{th} \approx 31.6$), C_4F_{10} ($< n > \approx 1.0014$, $\gamma_{th} \approx 18.9$) and C_5F_{12} ($< n > \approx 1.002$, $\gamma_{th} \approx 15.84$). These gases on the contrary of hydrocarbons, are not flammable. CF_4 has a drawback consisting in a consistent emission of scintillation photons, when it is crossed by a charged particle. The scintillation in CF_4 produces a number of photons N_{ph} = 1200/MeV [1], that represent an important source of background. The disadvantage of C_5F_{12} is its boiling point at 28 °C which requires heating of the detector to keep the radiator in a gaseous state. C_4F_{10} on the other hand does not produces scintillation, and has good transmittance properties; and its boiling point is T_b = -2 °C, so that it is in the gaseous state at ambient temperatures. We therefore restrict our considerations to the latter gas. The radiator length is chosen to be at least 80 cm in all parts of the detector. The mirror edges determine the length of the detector to satisfy the requirement. It is also the largest radiator length given the limited available space in the ALICE cavern.

For the photon detector we have two possibilities:

(a) A pad-segmented CsI photocathode The chamber has the same structure and characteristics of that used in the High Momentum Particle Identification (HMPID) detector [2]. The gas is CH_4, the pads size is 0.8×0.84 cm^2 (wire pitch 4.2 mm), and the single electron pulse height is of 34 ADC channels. The chamber is separated from the radiator by a SiO_2 window. (b) A TGEM-like detector combined with a reflective CsI photocathode. Our preliminary measurements show that with the TGEM-like detectors one can achieve quantum efficiencies for CsI similar to the ones achieved with a MWPC with a pad segmented photocathode covered with CsI. The advantage of the TGEM-like detector is the possibility to operate at higher gains due to the photon feedback suppression by the hole-type geometry. An interesting possibility would arise if it would be possible to operate the thick TGEM-like structure in the radiator gas.

The geometry that has been chosen exploits the focusing properties of a spherical mirror of radius R, successfully used in many RICH detectors. The photons emitted in the radiator are focused in a plane that is located at R/2 from the mirror center. In Fig. 1 a schematic view of the detector is shown. The detector dimensions are $80 \times 100 \times 100$ cm^3, the mirror radius of curvature is R = 160 cm. The radiator gas used is the C_4F_{10}, the window consists of 4 mm of SiO_2. Simulations of the performances have been executed. AliRoot, the official simulation framework of the ALICE experiment has been used. In Fig. 2 is shown the distribution of the number of detected photons and of photon clusters per event for a charged particle at saturation. A charged particle at saturation produces 20 photoelectrons and 12 photon clusters on average.

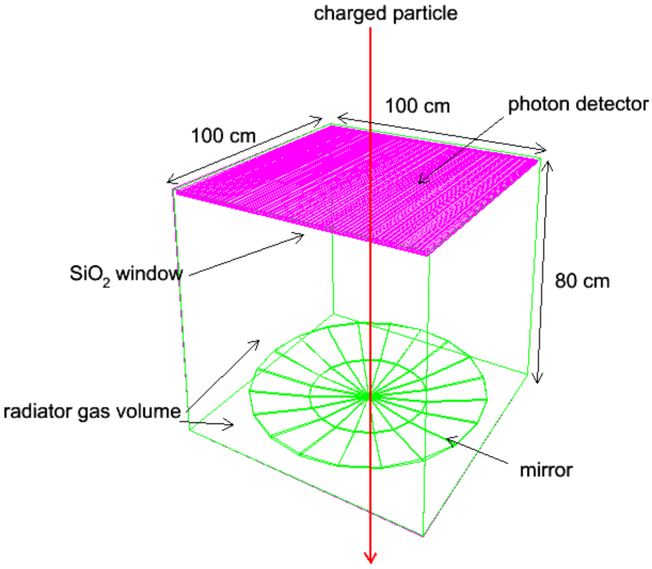

FIGURE 1. *Schematic picture of focusing design.*

The focusing properties of this setup enable measuring the emission Cherenkov angles. A pattern recognition algorithm has been implemented. Starting from the impact point of charged particles and of photons on the chamber, by means of a back-tracing algorithm the photon emission angle has been retrieved. Pattern recognition has been implemented in the presence of background given by Pb-Pb collision at LHC energies. In this case, to identify the signal from the background the Hough Transform procedure has been applied [3, 4].

Figure 2 is the distribution of the number of detected photons and of photon clusters per event for a charged particle at saturation with the standard pads and the 10 × 10 mm^2. In Fig. 3 the angle distribution for single cluster is shown, it is possible to see the photon signal and the background.

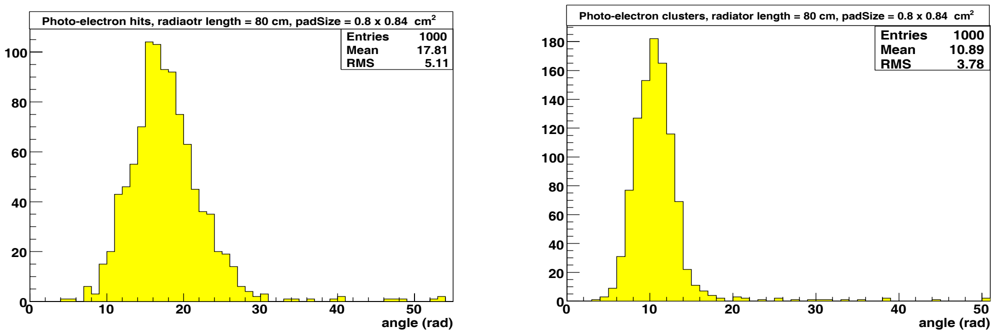

FIGURE 2. *Left: Distribution of the number of photoelectrons per event, for a charged particle at saturation. Right: Distribution of the number of photon cluster per event, for a charged particle at saturation.*

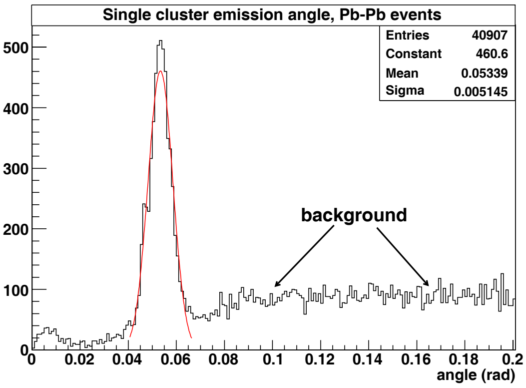

FIGURE 3. *Distribution of single cluster angle in presence of Pb-Pb background.*

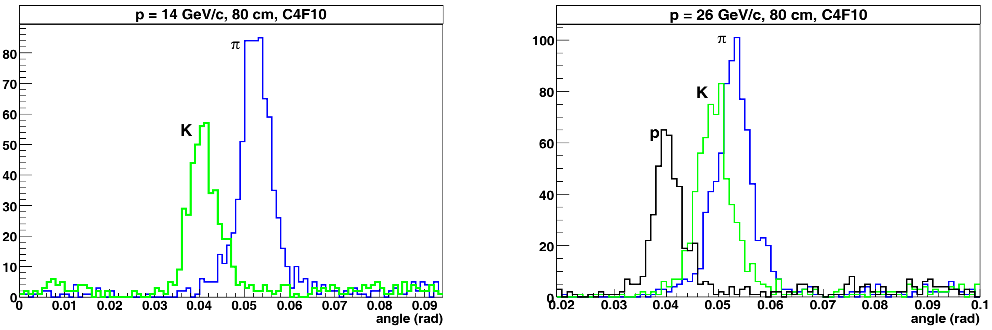

FIGURE 4. *Left: Distribution of ring angle, for pions and kaons of 14 GeV/c in presence of Pb-Pb background. Right: Distribution of ring angle for pions, kaons and protons of 26 GeV/c in presence of Pb-Pb background.*

In Fig. 4 are shown the results for pions, kaons and protons of 14 GeV/c and 26 GeV/c, embedded in a HIJING event using the Hough Transform method. Note that in this figure is included the presence of background given by Pb-Pb collisions. The summary of the PID separation for the VHMPID is given in Table 1.

TABLE 1. *Identification capabilities for the VHMPID*

Identification momentum range		
particle	Signal (GeV/c)	Absence of signal (GeV/c)
π	3 - 14	
k	9 - 14	
p	18 - 24	9 - 18

The detector design will be strongly affected by the limited space available inside the ALICE solenoid. The free space under the space-frame sectors 13 and 14 allows integrating maximum six modules on each side of the PHOS cradle (Fig. 5). With a size of 960 $\times$ 1400 mm^2 of area and 100 cm of height.

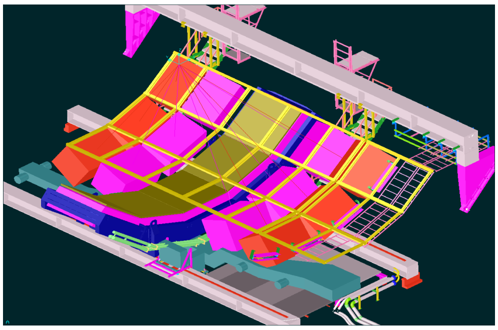

FIGURE 5. *1 3-D model of the proposed VHMPID layout with six modules on each side of the PHOS detector.*

The scarcity of particles with momenta $>$ 10 GeV/c requires an adequate triggering. At present we are investigating several possibilities: triggering with the signal in the EMCAL, triggering on high momentum particles in the Transition Radiation Detector of ALICE and finally a stand alone trigger in front of the VHMPID consisting of layers of gas electron multiplier (TGEM) to distinguish the curvature of the particles.We believe that a track by track identification of mesons and baryons could be a very important addition to ALICE.

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