Gas Cherenkov detectors for high momentum charged particle identification in ALICE

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Abstract

One of the most interesting results from heavy ion collisions at RHIC is the anomalously high baryon to meson ratio, in the so called intermediate momentum range of 2 to 6 GeV/c. To be able to study this phenomenon in details, all planned detector systems upgrades will extend the capability to identify protons up to 10 GeV/c and more. According to current models, the same phenomenon will be present at LHC at a higher momentum. We present an exhaustive study of the possibilities offered by a combination of a heavy gas radiator, of the highest index of refraction (C_5F_{12}), with the proven concept of large area CsI photocathodes, instrumenting either a multiwire chamber or a GEM detector. Three geometries have been investigated. Two of them, making no use of focusing, nevertheless allow identification in a large momentum range, 5-30 GeV/c for protons and from 5-15 GeV/c for kaons, combining the absence of signal, as in a threshold detector, with different parameters of the signal when the proton momentum is above the threshold. The third geometry deals with the possibilities of using a spherical mirror. Detailed simulations of the performance, in the environment of heavy ion central collisions at LHC energies, will be presented.

Key words: Cherenkov; Particle Identification
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1 Introduction

The results of RHIC [1,2], and earlier results of the experiment E735 for identified particles, indicate that the details of the hadronization are not well understood. For instance the p/π ratio, measured in heavy ion collisions and in pp collisions, have raised the so called baryon puzzle. This indicates that it is of fundamental importance to measure and understand the hadronization processes, as they will manifest themselves in pp and heavy-ion collisions at LHC. Today, in ALICE, the reach of proton identification on track-by-track basis is up to 5 GeV/c using the HMPID [3,4] and statistical identification is possible up to 30 GeV/c, using the relativistic rise in the TPC [5]. We have initiated a study about the possibilities to identify protons track-by-track, in a wider momentum range than it is possible with today's experiments. The task is complicated for several reasons; the detector has to be inside the magnetic field of the experiment, it has to be of sufficient granularity to ensure good separation of signal and background, it has to follow the space constraints of ALICE apparatus and finally it has to have a good identification property in a wide momentum range. In the present note we give account of different geometries considered in simulations of the possible detector, starting with a design used previously in heavy ion fixed target experiments - the Threshold Imaging Cherenkov (TIC) [6–8], followed by two other designs with and without focusing [8,9].

All three types use CsI photocathodes in a MWPC and C_5F_{12} as gas radiator. All simulations are based on actual values of the CsI quantum efficiency and the gas and window transmittance. The radiator refractive index and the transmittance values of the detector materials are shown in Fig.1 and in Fig.2 respectively.

2 Geometries

2.1 Detector using only Cherenkov photons

The first design we studied was the one where one prevents the ionization due to the charged tracks to reach the photon detector. This approach offers a smaller background than other solutions, albeit with drawbacks that prevent the use of this geometry in a large surface detector. In Fig. 3 we show the geometry of this type of detector following the TIC design. The elimination of charged particles is achieved positioning the mirror on the side of the detector, reflecting the Cherenkov Photons created in the gas with a 45 degree mirror. The detector dimensions are $180\times132\times42$ cm^3, the window and the

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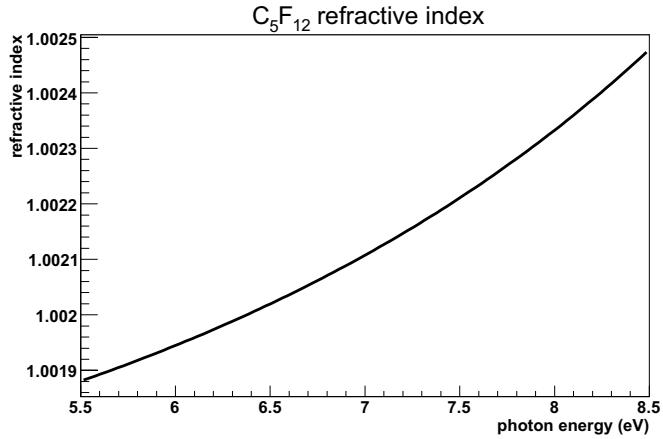


Fig. 1. *C_5F_{12} radiator refractive index as function of photon energy.*

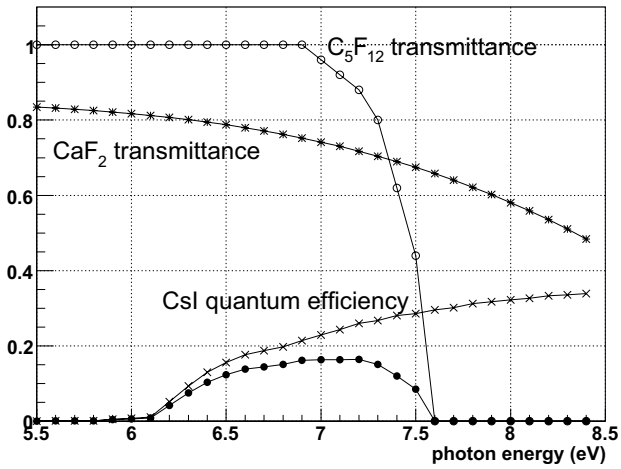


Fig. 2. *Transmittance of detector materials, CsI quantum efficiency and total convolution.*

mirror are 4 mm and 1 cm of thickness, respectively. The identification can be achieved twofold: either by the absence of signal in the detector (the tracking allows determining whether a particle created photons in the fiducial area of the detector or not) or if the particle is above threshold, to measure the dimension (radius) of the blob in detector to identify above the threshold. In Fig.4 and Fig.5 the blob registered in the photon detector for one and for ten superimposed pions events, of momentum close to the threshold (3 GeV/c) and of $\beta \approx 1$ (15 GeV/c) is shown. The blob diameter is determined in the following way: it is determined as the maximum distance passing through the center of the blob determined through tracking leaving out 2% of the farthest hits. The identification curves are shown in Fig.6, the error bars are the RMS value of the sample.

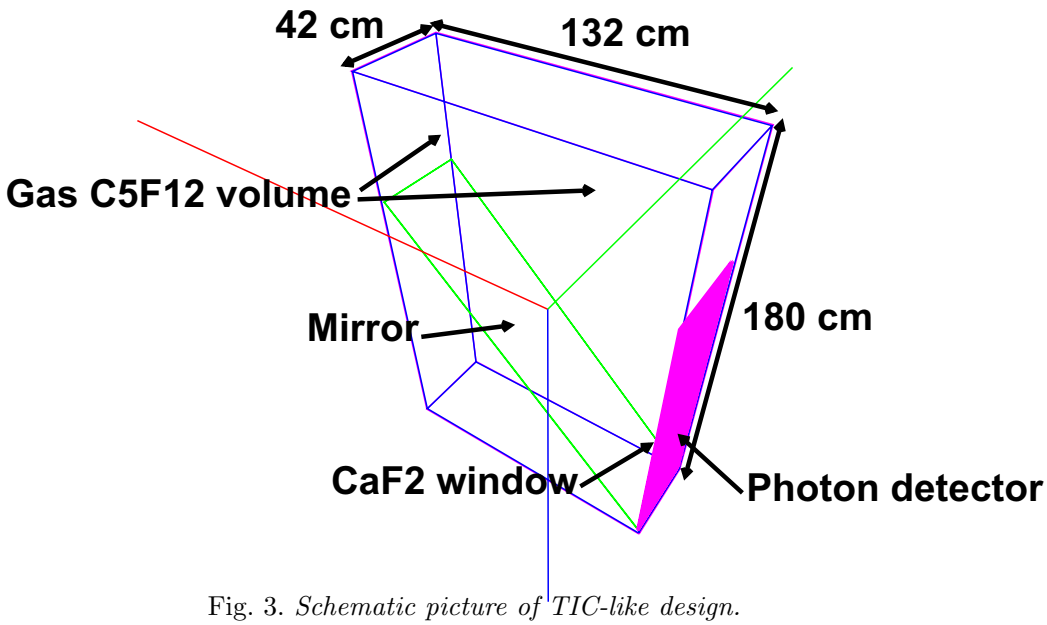


Fig. 3. *Schematic picture of TIC-like design.*

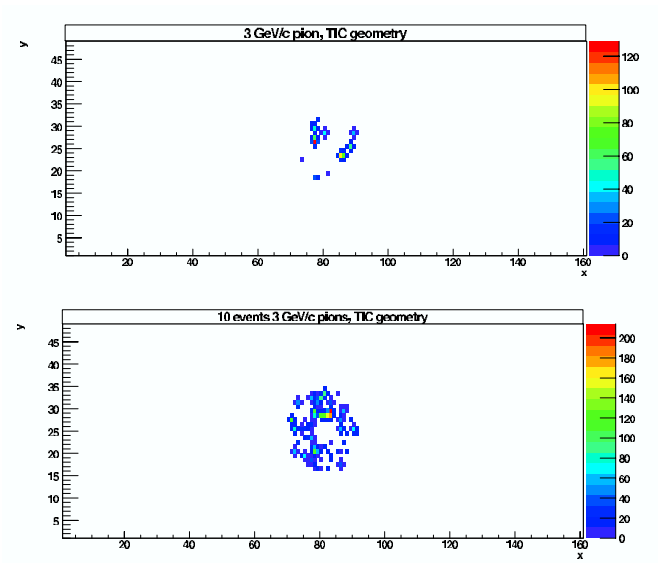


Fig. 4. *Blob of hit pads belonging to photons produced by 1 pion (top) and by 10 pions superimposed (bottom) of 3 GeV/c. The color scale reflects the collected charge on each pad.*

The drawback of this design is that the number of detected photoelectrons depends, for a given momentum, on the track length in the radiator which is not constant due to the mirror. This prevents building large detectors without segmentation. To avoid this problem should be possible to shape in a different way the radiator vessel. However, the absence of the ionization signal may also make the tracking elaborate. We have for these reasons discarded further

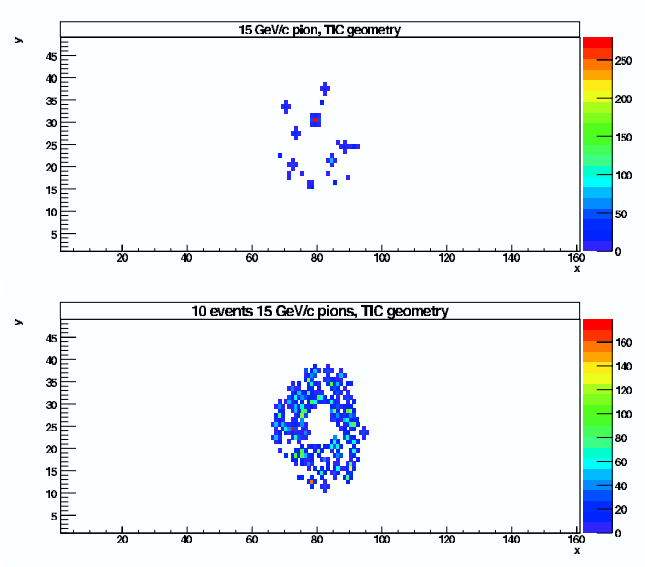


Fig. 5. *Blob of hit pads belonging to photons produced by 1 pion (top) and by 10 pions superimposed (bottom) of 15 GeV/c. The color scale reflects the collected charge on each pad.*

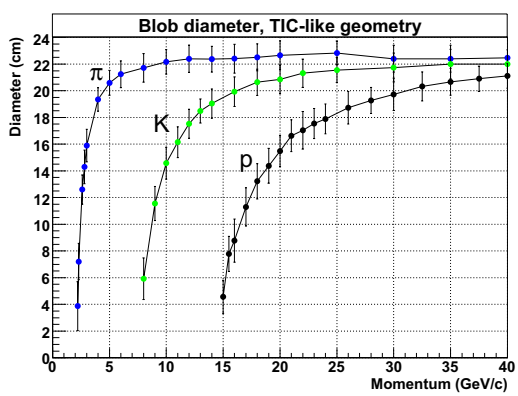
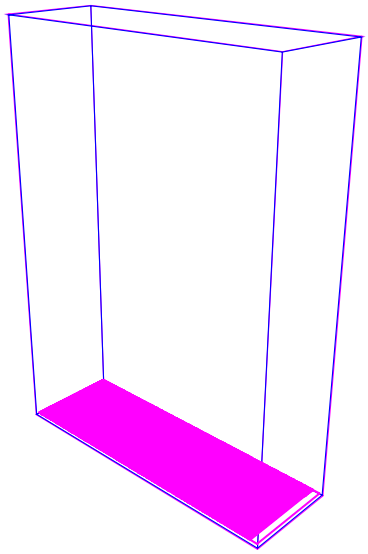


Fig. 6. *Blob diameter as a function of particle's momentum, for the the TIC setup.*

studies on this design.

2.2 Proximity-focusing type

To circumvent the above problems we have next studied a detector which has the classical design of a proximity focusing RICH, albeit with a radiator length that is large compared with the distance from the end radiator window to the photon detector. In the geometry shown in Fig.7, the particle track itself crosses the photon detector as well as the Cherenkov photons. The resulting patterns are shown in Fig.8 and Fig.9. The tracks leave intense ionization signal in the detector which is well visible in the events shown. The radiator