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A progress report on the development of the CsI-RICH detector for the ALICE experiment at LHC

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Abstract

The particle identification in ALICE (A Large Ion Collider Experiment) at LHC will be achieved by two complementary systems based on time-of-flight measurement, at low p_t, and on the Ring Imaging Cherenkov (RICH) technique, at p_t ranging from 2 to 5 GeV/c, respectively. The High Momentum PID (HMPID) system will cover $\sim 5\%$ of the phase space, the single-arm detector array being composed by seven $1.3 \times 1.3\,m^2$ CsI-RICH modules placed at 4.7 m from the interaction point where a density of about 50 particles/m^2 is expected.

A $1\,m^2$ prototype, $\frac{2}{3}$ of HMPID module size, has been successfully tested at the CERN/PS beam where 18 photoelectrons per event have been obtained with 3 GeV/c pions and 10 mm liquid C_6F_{14} radiator. Mechanical problems related to the liquid radiator vessel construction have been solved and the prototype, fully equipped, will be tested at the CERN/SPS to investigate the PID capability in high particle density events.

In this report, after an introductory discussion on the requirements for PID in ALICE, the HMPID prototype is described and the main results of beam tests on large area CsI photocathodes, operated in RICH detectors, are given. © 1998 Elsevier Science B.V. All rights reserved.

1. Introduction

ALICE (A large Ion Collider Experiment) is the only LHC experiment fully dedicated to the study of heavy-ion collisions and it will address most of the hadronic and leptonic signals of Quark-Gluon-Plasma (QGP) formation. In ^{207}Pb–^{207}Pb collisions, at 2.76 TeV/nucleon, low interaction rates ($\leq$ 10 kHz with about 10% of central events) and high multiplicities ($\sim$ 8000 particles per rapidity unit) are expected. A detailed description of ALICE can be found in Refs. [1,2].

Particle identification (PID) is an important design feature in ALICE, because of the large spectra of momenta and masses that will be measured. In the momentum range below 2 GeV/c, where the bulk of hadrons is concentrated, the PID will be

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accomplished by TOF measurement in a barrel system. Only 3% of the produced hadrons will have p_t larger than 2 GeV/c, a feature which makes this region accessible only to inclusive measurements. A dedicated High-Momentum PID (HMPID) system has been designed to measure inclusive particle ratios and p_t spectra in the range 2–5 GeV/c. It is a single arm array of seven $1.3 \times 1.3\,m^2$ CsI-RICH modules covering about $12\,m^2$, namely 5% of full central acceptance (Fig. 1). The detector segmentation and the tilting of the modules decrease the scatter of the incident angles of the particles (limiting them to a $0°$–$15°$ spread); this minimizes Cherenkov photons total internal reflection losses in the radiator and improves the identification capability. The RICH modules are placed at 4.7 m from the interaction vertex, position corresponding to multiplicities $\leq$ 50 particles/m^2 (including expected background). To verify the PID capabilities in such conditions of particle density a $1\,m^2$ prototype has been built to be tested at the CERN/SPS. In this report a description of the prototype and main test beam results on large area CsI-RICH detector are presented.

2. The HMPID RICH prototype

The RICH detector has a proximity focusing geometry, with 10 mm liquid C_6F_{14} radiator, suitable for the momentum range of interest, coupled through a 5 mm quartz window to a multiwire chamber (MWPC, 4 mm anode wire pitch, 2 mm anode–cathode gap) with a cathode segmented into $8 \times 8\,mm^2$ pads for 2-D readout [1]. A 500 nm photosensitive CsI film evaporated on the pads converts the Cherenkov photons into single electrons originating avalanches at the MWPC anode wires. The analog readout of the pads allows accurate localization through centroids evaluation. The use of a solid photoconverter permits thin sensitive gaps in the MWPC, resulting in a considerable reduction of the background from ionizing particles. This feature is mandatory with the expected multiplicity which makes the pattern recognition capability a prime requirement for our application. The photodetector can even be used as an additional tracking plane with good position resolution [1,3].

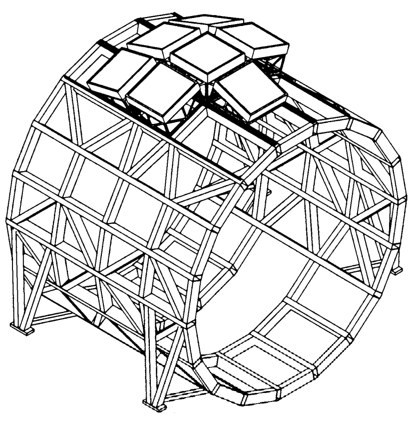

Fig. 1. Perspective view of the HMPID system with the 7 RICH modules placed on top of the barrel frame and tilted according to the distance from the interaction point.

The HMPID requirements make acceptance less crucial than performance, thus allowing some dead space in the detector plane. Therefore, to optimize the production procedure and to ease the handling, the photocathode (PC) and the radiator have been segmented into $64 \times 40\,cm^2$ panels and $130 \times 42\,cm^2$ vessels (Fig. 2).

The HMPID prototype is $130 \times 85\,cm^2$, namely $\frac{2}{3}$ of one RICH module size. It has been successfully tested at the CERN/PS test beam, demonstrating not only the good operation of the MWPC, having 1.3 m long anode wires and a support line in the middle, but also the feasibility and the mounting under clean controlled specifications of $64 \times 40\,cm^2$ CsI PCs. The prototype will be completely equipped, with full size radiator vessels, to be tested at the CERN/SPS.

The designed radiator vessel consists of a NEOCERAM (NIPPON GLASS, Japan) tray closed by a fused silica SUPRASIL window. The two materials have equal thermal dilation coefficients and the resulting container is characterized by the stiffness required to cope with the C_6F_{14} hydrostatic pressure. The vessel-strain under hydrostatic load, in every position foreseen by the HMPID detector design, has been measured on a full size vessel and the results have confirmed the mechanical design expectations.

The ALICE low interaction rates allow multiplexed analog readout based on full custom

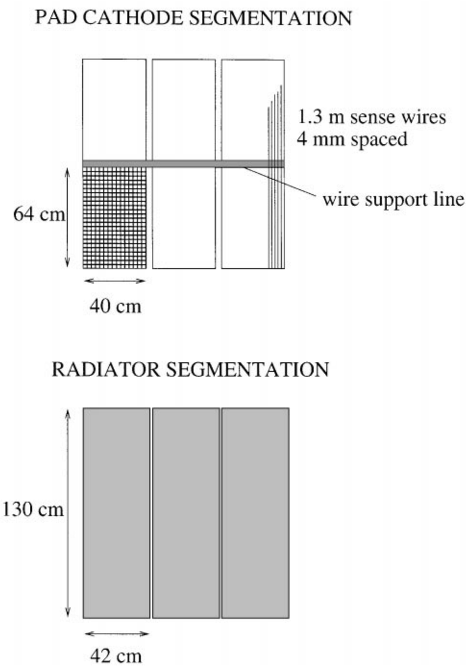

Fig. 2. Segmentation of pad cathode and radiator.

electronics. Currently, the frontend electronics of the RICH prototype is based on the 16 channel GASSIPLEX chip [4]. In the final detector version it will be based on the MultiChip Module (MCM) DIGITPLEX, composed by 4 GASSIPLEXs, the 10 bit ADC CRIAD and the zero suppression chip DILOGIC on a board [5]. The specifications are: ECN $< 800\ e^-$ at 20 pF input, baseline restoration $< 0.5\%$ after 3 μs, data ready after zero suppression for 64 channels in 3 μs.

3. Test beam results on large-area CsI-RICH detectors

The HMPID requirements have directed the choice towards a fast-RICH configuration with CsI PC, which has been made possible by the CERN/RD26 project activities demonstrating the feasibility of large-area CsI photocathodes with high and stable quantum efficiency [6]. The QE of 29 large PCs, produced at CERN, has been evaluated, exploiting the Cherenkov radiation in a RICH detector in test beam. A detailed presentation of the RD26 results can be found in Ref. [7].

Fig. 3 shows the CsI QE measured at 170 nm as a function of the PC production number, summarizing the results of 4 years activity. The improvement can be attributed to the definition of a new procedure to produce the photocathodes. Firstly, the substrate is obtained by chemical deposition of nickel and gold layers on top of the copper pads, previously mechanically and chemically polished. Then the CsI is evaporated at 50°C and 10^{-6} Torr, and the PC is kept under vacuum at 50°C for six hours.

Another important feature is the QE stability: two PCs, among the best ones, kept under argon (between beam test periods) and periodically tested, show QE degradation less than 5% in two years (Fig. 4).

Fig. 5 shows typical 3 GeV/c pion events obtained at the CERN/PS test beam. Each PC is tested at several MWPC gains and Cherenkov radiator thickness and the photodetector performance is evaluated by means of dedicated analysis and simulation programs. The main event quantities are extracted by the analysis program from a fiducial region of the PC plane where all the Cherenkov photons hits are expected (Fig. 6). Then these quantities are reproduced by the Monte

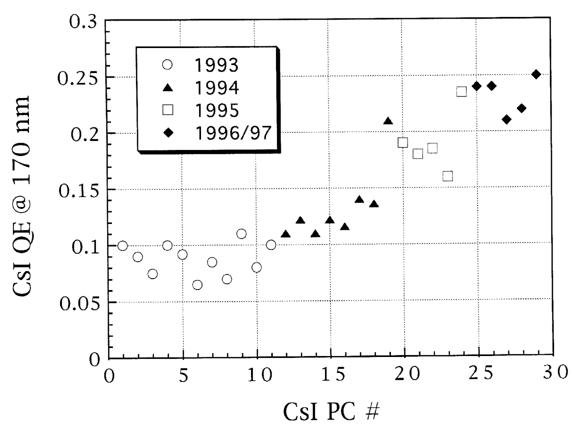

Fig. 3. CsI QE measured at 170 nm as a function of the PC number. All the photocathodes have large area, from 30×30 to $64 \times 40\,cm^2$ of PC 28 and 29 which have been produced for the HMPID prototype.

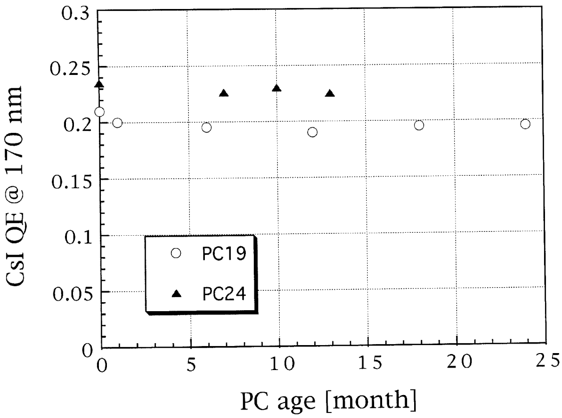

Fig. 4. CsI QE measured at 170 nm as a function of PC age.

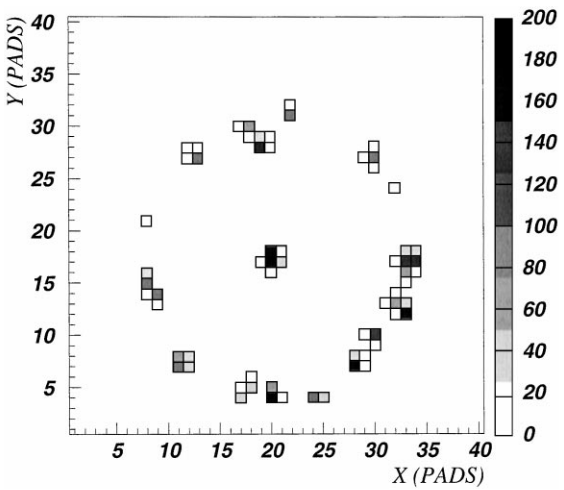

Fig. 5. A 3 GeV/c pion event, obtained with PC24 and 10 mm thick C_6F_{14} radiator, showing the pad cluster MIP surrounded by the Cherenkov photons ring. The ring radius of about 10 cm has been obtained with a proximity gap of 7 cm. The grey scale on the right, in arbitrary units, is proportional to the signal measured on the pads.

Carlo simulation, allowing to estimate CsI photoelectric yield and the photon feedback contribution. An essential feature, that the simulation program has permitted to observe, is the spatial distribution of feedback photons: due to the small anode–cathode gap and the pad size, they overlap to the cluster originated by the primary Cherenkov photon, thus resulting in a very small background.

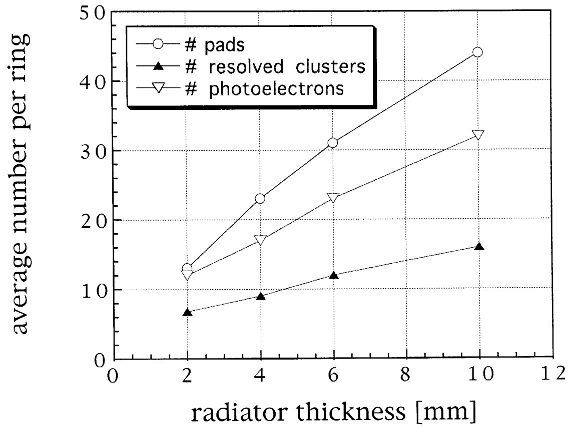

Fig. 6. Average number of pads, pad clusters and photoelectrons as a function of the C_6F_{14} radiator thickness, at a gain of 10^5 and with 3 GeV/c pions. The number of photoelectrons, obtained as ratio between the total pulse height and the single electron pulse height, includes Cherenkov and feedback photons, while the number of resolved clusters is related to Cherenkov events. The mean number of pads per event depends on the cluster size, which varies roughly from 2 to 3 pads in the 2–10 mm radiator thickness range. The cluster size increase with radiator thickness can be attributed to photoelectrons overlapping, which enhances the signal induced on pads and therefore the number of pads being over threshold.

The main test beam results can be summarized as follows:

1. a very stable, discharge-free, operation of the MWPC at a gain of $\sim 10^5$ and single electron detection efficiency of 95%,
2. average number of 18 Cherenkov photoelectrons per ring with 3 GeV/c pion and 10 mm C_6F_{14} radiator;
3. single photon angular resolution of 8 mrad.

Furthermore, two $80 \times 20\,cm^2$ CsI photocathodes have been successfully used in the threshold imaging Cherenkov detector of the CERN/NA44 experiment, showing no degradation of the performance during four weeks of high irradiation level in lead ion run [8].

4. Conclusions

The status of the development of the CsI-RICH detector for the HMPID in ALICE at LHC has reached a very important phase. A prototype, $\frac{2}{3}$ of one final RICH module, has been built, confirming mechanical design expectations and showing also good performance of the MWPC with large area CsI photocathode. The foreseen test at the CERN/SPS will be of prime importance to assess the PID capability in events with high particle densities.

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