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Presented by A. Di Mauro

Abstract

The ALICE HMPID RICH detector is equipped with CsI photocathodes in a MWPC for the detection of Cherenkov photons. The long term operational experience with large area CsI photocathodes will be described. The RICH prototypes have shown a very high stability of operation and performance, at a gain of 10^5 and with rates up to $2x10^4$ cm^{-2} s^{-1}. When exposure to air has been avoided, no degradation of the CsI quantum efficiency has been observed on photocathodes periodically exposed to test-beams over 7 years, corresponding to local integrated charge densities of ~ 1 mC cm^{-2}. The results of limited exposures to oxygen and humidity will also be presented.

1. Introduction

ALICE is the only LHC experiment dedicated to the heavy ion physics [1]; it will study p-p, p-A and A-A collisions at a center of mass energy •s = 5.5 A TeV. The ALICE High Momentum Particle IDentification (HMPID) system is based on a RICH detector equipped with CsI photocathodes (PCs) for the detection of the Cherenkov light [2]. In Pb-Pb collisions, at the highest predicted multiplicity dN_{ch}/dy ~ 8000, 100 charged particles/m^2 are expected to cross the HMPID detector, located at 5 m from the vertex, with an interaction rate of 8 kHz.

Several groups have investigated CsI thin film aging in the last years, however it is neither well quantified nor fully understood. The basic processes and a collection of data are reviewed in [2,3,4,5]. The quantum efficiency (QE) of a CsI PC may degrade

due to modifications of the crystal lattice structure and stoichiometry. CsI and the single elements Cs and I react rapidly with water; Cs also easily oxidizes [6]. Since any exposure to air has to be avoided, the handling and the mounting on detector may be difficult, especially with large PCs (~ 50x50 cm^2). QE degradation can also be generated by the impact of the avalanche ions, when the PCs are operated in a gaseous detector, or by the photon flux only (without charge multiplication). Other degradation sources may be the contamination of the surface by impurities (which will not be treated in this paper) and the radiation damages by neutral or charged particles.

Usually, aging studies are carried out on small CsI samples, through accelerated tests reaching, in few weeks or months, integrated charges comparable to several years of operation in the anticipated environment of the experiment. In the present paper, we will describe our long term experience with large area CsI PCs, periodically exposed to test-beam and also used in the STAR experiment at BNL. The results of exposures to high levels of oxygen or water vapour will also be presented.

2. Detector description and PCs characteristics

Fig. 1 shows the principle scheme of the CsI-RICH detector; a detailed description can be found in [2,7]. The HMPID RICH has a proximity focusing geometry; the radiator, 15 mm thick, is liquid C_6F_{14} contained in a Neoceram® tray with a 5 mm fused silica exit window to transmit the UV Cherenkov photons. The photon detector is a MWPC, 4 mm sensitive gap, 20 μm anode wires with 4.2 mm pitch, operated with CH_4 at atmospheric pressure and having a pad cathode coated with a 300 nm photosensitive layer of CsI.

Within the CERN project RD26, 32 CsI PCs, having area from 20x10 to 64x40 cm^2, have been produced in the period 1993-1997 [8]. This project, aiming at the study of photosensitive CsI films for the detection of Cherenkov light, allowed the definition of a procedure to prepare large area CsI PCs with reproducible high QE. Fig. 2 presents the QE at 170 nm of the produced PCs, including the last five recently produced in the frame of the HMPID project. The improvement observed with PC19 was due to a

new substrate preparation (Cu-clad PCB coated with Ni/Au layers and polished), to the heat treatment and to the use of a dedicated transfer system for the detector assembly, to avoid exposure to air [2,9].
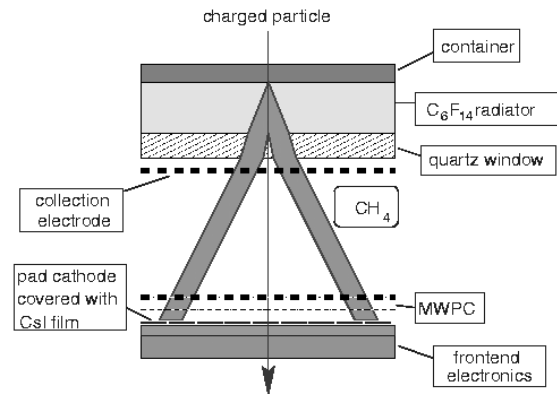

Fig. 1 Schematic view of the proximity focusing CsI-RICH detector. The lateral section of the cone represents the emitted Cherenkov light.
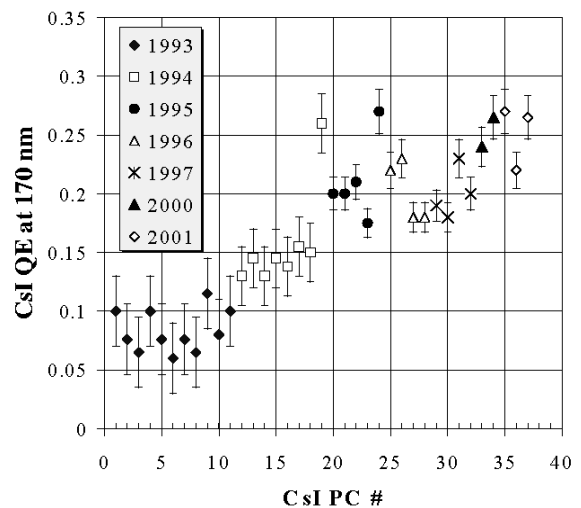

Fig. 2 Overview of the QE measured at 170 nm of the CsI PCs produced for the HMPID detector prototypes.

The PCs selected for this study are: PC19, PC24, PC29, PC30, PC31 and PC32. PC19 and PC24 were produced in November 1994 and December 1995, respectively. They measure 30x32 cm^2 and are used in the HMPID RICH proto-1. PC29 to PC32 have an area of 40x64 cm^2 and were produced during June and July 1997. They are part of the larger proto-2, measuring 2/3 of a full HMPID module that is equipped with six PCs. At the end of 1999 proto-2 has been installed in the STAR experiment at BNL.

3. QE extraction from test-beam data

The PCs QE is deduced from test-beam data with a procedure fully described in [10] and based on the comparison between experimental results and Monte Carlo simulation of Cherenkov events. Series of runs are taken, varying the anode wires high voltage and (only with proto-1) the radiator thickness or the proximity gap. Then, the main steps of the analysis are:

a) definition of a fiducial area which includes all Cherenkov photons that reach the PC, depending on the detector geometry and the beam momentum (fig. 3);

b) pad clusters analysis and deconvolution, to locate single photoelectron clusters and measure the chamber gain (single electron mean pulse height);

c) evaluation of the main quantities: clusters multiplicity and size, total pad hits, ring radius spread, Cherenkov angle resolution;

d) tuning of a CsI QE curve by a Monte Carlo detector simulation, where all the processes, from the Cherenkov photons generation up to the signal induced on the pads, are taken into account.

Fig. 4 shows the differential QE of PC19, measured in different test-beams over a period of 7 years.

4. Operational experience with CsI PCs

Following a first performance evaluation just after production, the PCs have been re-evaluated several times with test-beams of the RICH prototypes to monitor their stability. For each PC, a large collection of data has been reviewed to point out the correlation between any observed QE decrease and the possible contact with aging sources.
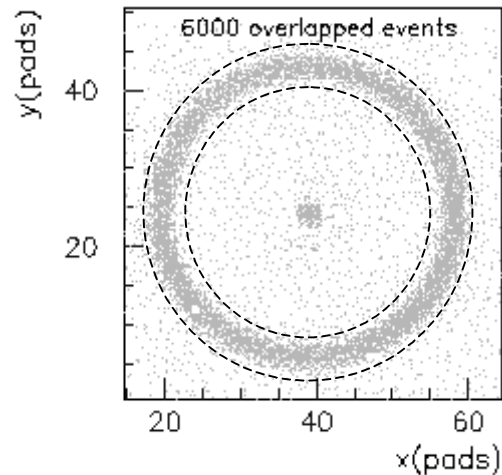

Fig. 3 Pad hits produced by 6000 overlapped Cherenkov events generated by 350 GeV/c pion, with 10 mm of C_6F_{14} and a proximity gap of 100 mm. The pad size is 8x8 mm^2. The dashed lines delimit the fiducial area of the Cherenkov photons, while the spot in the center corresponds to the particles traversing the detector in a 1 cm^2 area as defined by the event trigger scintillators.
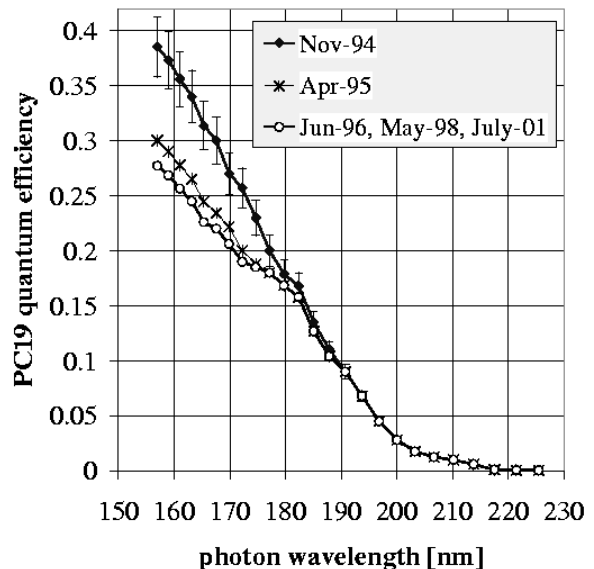

Fig. 4 PC19 differential QE, from the production date, Nov-94, until July-01, extracted from test-beam data. The degradation observed after the production was due to exposure to air.

4.1. Detector aging

It is worth to mention that all the HMPID RICH prototypes are made out of aluminum frames and have been assembled using standard construction materials (e.g. G10, Araldite AW106, Viton o-rings). During several years of use, under a gas gain of 10^5 and irradiation rates of ~10^4 cm^{-2} s^{-1}, no symptoms of detector aging (gain decay, Malter effect, discharges) have been observed.

4.2. PCs aging

The experimental conditions have to be considered in order to estimate the contribution of the different aging sources: the exposure to O_2 and H_2O, the accumulated charge density corresponding to ion impact and the total integrated photon flux.

i) *Exposure to O_2 and H_2O*

After the CsI coating, the PC is transferred into a storage protective box without any exposure to air and kept constantly under Ar flow (10-20 l/h), at O_2 and H_2O levels lower than 10 ppm. At each test-beam, mounting and dismounting on the detector are executed inside a glove box, with an exposure for about 1 h to 400 ppm of O_2 and 100 ppm of H_2O. Only PC19, when such a glove box was not yet available, has experienced three assembly operations in air, under relative humidity of 50%. During the beam test the contaminants concentration is generally lower than 10 ppm.

Dedicated tests have also been carried out with high levels of O_2 and H_2O, in stagnant conditions or under gas flow [11]. The PCs were checked with test-beam before and soon after the exposures and no change in the QE has been noticed. The results of this study have been used to plan the shipment by aircraft, of the four PCs, PC29 to PC32, for the installation of proto-2 in the STAR experiment at BNL. During the shipment the PCs were kept inside sealed vessels pressurized with Ar at 1.2 bar.

ii) *Ion impact.*

To evaluate the accumulated charge density, one has to distinguish between avalanches produced by charged particles and those generated by single photoelectrons.

a) *PC19 and PC24* - These PCs, mounted on proto-1, have been irradiated always with the beam crossing the detector in the center (Fig. 3). In this case, the area illuminated by the Cherenkov radiation is fixed and aging inside this area (measuring about 200 cm^2) may be produced only by ion impact related to Cherenkov photons. At a gain of 10^5 and with an average of 20 photoelectrons per event, up to 10 µC/cm^2 are accumulated inside such a fiducial area, during one week of beam tests exposure.

b) *PC29 to PC32* - Given their larger size, the QE of these PCs has been evaluated by means of a test-beam scan in three different fixed locations (for each PC). The local irradiation, inside the 1 cm^2 beam fiducial area, is much higher than in the Cherenkov fiducial region, leading to a total accumulated charge density of the order of 1 mC cm^{-2}. (over all the periods of beam tests). Proto-2 has been also exposed to fixed target events at the CERN/SPS (350 GeV/c π^- on Be) and to Au-Au collision or cosmic rays events at STAR, with Cherenkov rings spread over the whole detector surface. For the π^--Be events, an average multiplicity of 100 particles/m^2 was measured inside an acceptance region of 5 cm radius, gathering up to 50 µC/cm^2, over the irradiated PC32 and PC31. For the Au-Au events, an average multiplicity of 20 particles/m^2 was measured in central events, collecting 20 µC/cm^2, over the whole photosensitive area.

iii) *Photon impact.*

The largest photon flux of 2×10^4 photons cm^{-2} s^{-1}, estimated inside the Cherenkov fiducial area, has been reached with the beam in fixed positions. This value is very far from the flux of 10^{12} cm^{-2} s^{-1} necessary to observe aging due to photon impact only. Results of this effect can be found in [3,4,12,13].

5. Selected PCs history and stability

Fig. 5 shows the evolution with time of the mean QE, over the wavelength range 155-210 nm, as a function of the PC age, for PC19 and PC24.

PC19 has undergone three mounting on detector without a glove-box, resulting in a QE decay of about 20%. However, in the following tests a remarkably constant performance has been observed, up to a total accumulated charge density of 50 µC/cm^2.
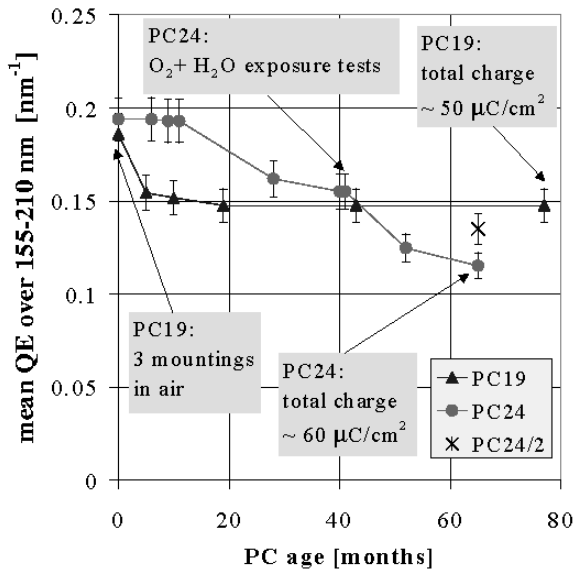
Fig. 5 Mean QE history of PC19 and PC24. The point labeled as PC24/2 refers to a different fiducial area than the usual one, obtained by reducing the proximity gap in proto-1.
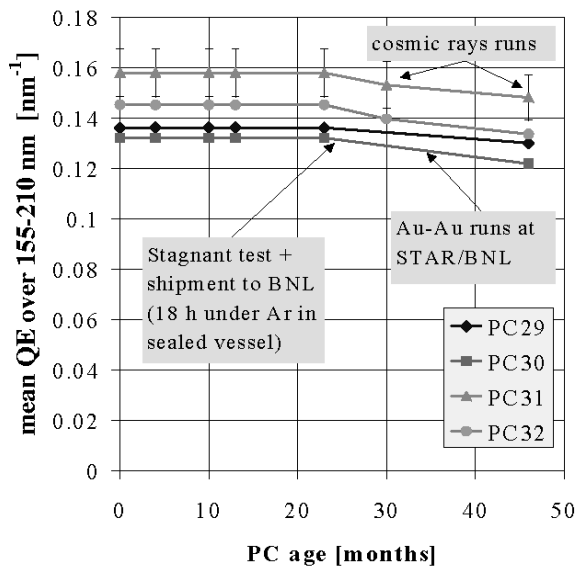
Fig. 6 Mean QE history of the proto-2 PCs (PC29 to PC32).

PC24 began to deteriorate after an initial stability, for reasons that are not yet clear. One possible origin could be a leak from the radiator causing an

accidental exposure to air and C_6F_{14}. Additionally, given the technology to produce the PC24 pad PCB for this PC, the presence of micro-leaks (caused by through-holes for pad-electronics connection) cannot be excluded. Afterwards, two kind of exposure tests were performed: (1) 24 h stagnant test, outgassing 10000 ppm of O_2 and 40 ppm of H_2O; (2) under Ar/dry air mixture flow, 6 and 18 h with 18000 ppm of O_2 and 6 h with 100000 ppm of O_2. Soon after each of these tests, no degradations were observed. However, the later checks have pointed out a worsening of the QE, with an increase of the aging slope. In addition, in the last test-beam, a different fiducial area has been investigated, resulting in a higher mean value of the QE. Considering that such a fiducial area was never illuminated with the Cherenkov radiation, this result seems to indicate that the exposure to pollutants is more effective when combined to ion impact.

Fig. 6 shows the variation with time of the mean QE of the proto-2 PCs (PC29 to PC32). The four PCs have shown very high stability up to a total collected charge density (over the whole detector photosensitive area) of 80 $\mu C/cm^2$. Before the shipment to BNL, the HMPID proto-2 was kept for 16 h without gas flow, with an overpressure of 3 mbar, reaching 5000 ppm of O_2 and 30 ppm of H_2O due to the outgassing. Even in this case, no variations of the QE have been detected soon after the test. However, this test and the shipment to BNL (18 h in a sealed container) might have initiated the small QE decrease (less than 10%), measured with two cosmic rays test periods.

On the other hand, about two years of operation at STAR have not affected the four PCs performance. In addition, the STAR and the cosmic rays runs have allowed to assess the PCs response inside the fixed beam fiducial areas, where up to ~ 1 mC cm^{-2} have been collected during the test-beam periods. Indeed, Fig. 7 shows the proto-2 pad map with 100000 overlapped STAR events. No dead or lower efficiency regions have been observed in such beam fixed locations, centered at the following pad coordinates: Y=24 and 72, X=20, 40, 60, 80, 100, and 120. For comparison, the charge density integrated over one year (10^6 s) Pb run at ALICE (with 3% central events) is expected to amount to 50 $\mu C/cm^2$.
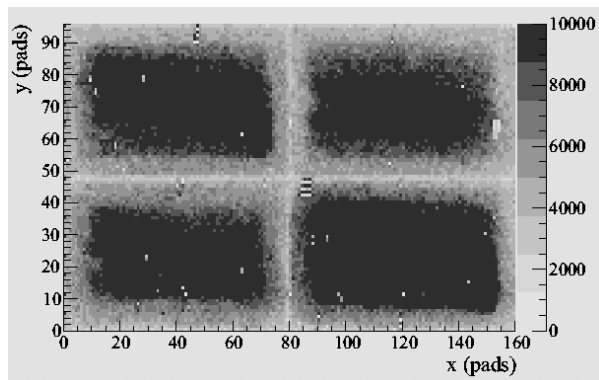
Fig. 7 Pad map of proto-2 obtained by overlapping 14000 STAR events. Only the hits originated by Cherenkov photons have been considered. The grey scale is proportional to the number of hits in each pad. The lower hits density close to the PCs contour is determined by the detector acceptance geometry, while the white spots are dead channels.

6. Experience with neutral particles

In 1995-96, a relevant information was obtained from the operation, during two periods of four weeks, of a CsI-based imaging detector in the NA44 experiment, using Pb beam on target at the CERN/SPS. PC21 and PC22 ($20x77$ cm^2) were installed in the photodetectors, as part of the Threshold Imaging Cherenkov detector (TIC) [14]. It was located close to the beam dump and delivered high burst current (100-400 nA). However, the magnetic spectrometer in use at NA44 was designed such that very few charged particles were traversing the gaseous radiator of the TIC, without even crossing the photodetectors. Hence, a large part of the current could have been produced by neutron conversions. During these periods, the PCs performance has been found stable and the detector operation satisfactory.

7. Conclusions

The long term operational experience with 6 large area CsI PCs, produced for the ALICE HMPID

prototypes, has been reviewed with respect to the main known aging sources: exposure to air and ion impact.

In PC19, a QE degradation of 20% has been observed after exposure to air for about 1 h at a relative humidity of 50%. The consequences of the contact with high levels (larger than 1000 ppm) of O_2 are not quite clear. However, it resulted to be more effective on a PC showing already some aging symptoms (PC24), than on the other more stable PCs (PC29 to PC32).

Irradiation at rates ~ 100 KHz, leading to local accumulated charge densities up to 1 mC cm^{-2}, has produced neither variations of the CsI QE nor detector performance instabilities. The PC response has been found very stable, provided the exposure to O_2 and H_2O was limited to the ppm level.

Acknowledgements

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