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R&D in ALICE: The CsI-based RICH high momentum particle identification detector

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Abstract. We report on the R&D studies performed on a CsI-based RICH detector with a liquid perfluorohexane radiator running pure methane at atmospheric pressure. The development, initiated by the CERN RD26 project in 1993, has been pursued in the framework of the ALICE/HMPID collaboration. A prototype of the detector under construction for ALICE is taking data since two years in the STAR experiment at RHIC.

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1 Introduction

A CsI-RICH detector has been chosen as the High-Momentum Particle IDentification (HMPID) system of the ALICE experiment. This detector will consist of seven modules of 1.3×1.3 m^2 each, for a total CsI area of about 11 m^2 and it aims to particle identification in the 1–5 GeV/c momentum range, complementing the ALICE barrel detectors above 2 GeV/c [1]. After a description of the detector, we will focus on three R&D items:

(i) The CsI photocathode (PC). The development of a reliable technology to produce large (64×40 cm^2) area PCs with high quantum efficiency (QE) has been started in 1993 by the RD26 collaboration and has led to the production of PCs of the required size having a QE exceeding 20% at 170 nm.

(ii) The development and construction of a 2/3 scale detector prototype. This detector is presently in use in the STAR experiment at RHIC (BNL) and preliminary physics results are already available.

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(iii) The development of two ASIC chips, one analog (GASSIPLEX) and one digital (DILOGIC), on which the front-end electronics (FEE) is based.

2 Detector description

Figure 1 shows the cutaway view of the proximity focussing CsI-RICH detector. The lateral section of the cone represents the emitted Cherenkov light.

Cherenkov photons are emitted while charged particles cross a 15 mm thick layer of liquid perfluorohexane (C_6F_{14}) circulated into a tray, closed by a 0.5 cm thick UV-grade fused silica plate. This liquid radiator medium is characterized by a refractive index (1.2989 at 175 nm)[1] and a low chromaticity adequate for particle identification in the momentum range required by ALICE. The Cherenkov photons impinge on the photodetector, separated from the radiator by a proximity gap of 80 mm such that Cherenkov rings of convenient size are obtained without a focusing device. The photodetector is a MWPC having a cathode covered with a CsI layer 300nm thick, acting as photoconverter. The same cathode is segmented into pads, of size 8×8.4 mm^2, in order to achieve the two-dimensional localization of the photoelectron mandatory in the ALICE high-density particle environment. The second cathode is made of 100 μm diameter gold plated copper beryllium wires, spaced by 2.1 mm and located at 2.2 mm from the anode plane. The anode plane, which is made of 20 μm gold plated tungsten rhenium wires, is located at 2 mm from the pad plane. The analog information from each pad is recorded by means of analog multiplexed electronics, implemented at the back of the pad plane, allowing for a uniform low thresholding of 0.6 ± 0.03 fC and accurate centroid localization. Pure methane is used as the MWPC gas since it is transparent to VUV radiation down to 130 nm and it allows the chamber to run in a stable manner at a gas gain of $\sim 10^5$ with no deterioration of quantum efficiency up to a rate density of $2.0 \times 10^4 \mathrm{s}^{-1}\mathrm{cm}^{-2}$. A more detailed description of the detector can be found in [1] and [2].

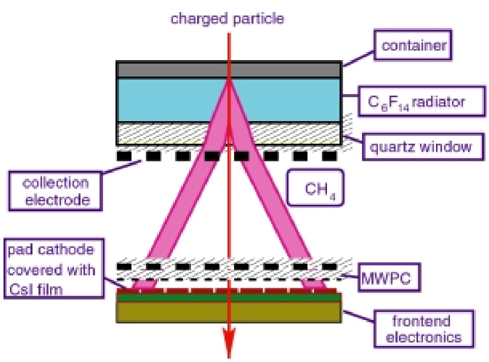

Fig. 1. Cutaway view of the HMPID detector

[1] $\beta_{min} = 0.77$, i.e. threshold momentum $p_{th} = 1.207 \times$ particle mass.

3 The CsI photocathode

The CsI layer (300 nm thickness) is evaporated under vacuum by Joule effect on a pad panel made of three elements: two multi-layer PCBs, on which the pad pattern is etched, are glued using a dedicated vacuum table on an aluminum frame. A flatness of ± 50 μm is achieved over an area of 64×40 cm^2. The structure is closed on the opposite side by a third PCB, the ground-PCB, to provide a good electromagnetic shielding. The electrical connection from the pads to the front-end electronics (FEE) is achieved by means of SMD connectors soldered on the multi-layer PCBs. Six photocathodes are needed to equip one HMPID module, for a total of 42 for the full detector.

A different mechanical assembly, based on a sandwich composite structure, has been widely and successfully used over the past 10 years and it is fully described in [1] and [2]. The present assembly has been adopted since it turns out to be cheaper and easier to assemble while providing improved flatness and quality reproducibility.

Besides acting as a pad-segmented MWPC cathode, the multi-layer PCB also acts as the substrate of the photocathode. After some development work, a dedicated PCB fabrication procedure was established such that large PCs with the required quantum efficiency can be produced with a good yield. Two main problems were identified:

(i) In order to avoid a destructive reactive contact between the CsI film and the copper substrate, it was decided to cover the copper surfaces with a 7 μm nickel layer.

(ii) More care was devoted to the surface preparation by using mechanical and chemical polishing, the later made possible by the new mechanical assembly.

The nickel layer is in turn covered with a layer of gold. Both chemical and electrolytic gold depositions have been tested without detectable differences in the QE performance.

A post-treatment after CsI coating at 60°C under vacuum during $\sim$12 hours is applied. Figure 2 shows the QE of two PCs (Proto3.1 and Proto3.2) built in November 2000 using the new technology compared to PC32 built using the old technology. The improvement described in (i) was already applied to the construction of PC32. In 2001 two more PCs with performance similar to Proto3.1 and 3.2 have been produced. For normal tracks and saturated ($\beta \sim 1$) rings the number of reconstructed photoelectrons is up to 17 ± 2. Figure 3 shows one Cherenkov event; the MIP signal is also clearly visible at the center of the ring.

CsI is known to be very hygroscopic and exposure to air should be avoided in order not to degrade the QE performance. For this reason the PCs are stored in aluminum protective boxes continuously flushed with argon. The mounting onto the detector is done in a glove box under argon atmosphere.

The influence of the exposure to O_2 and H_2O has also been investigated [6].

Monitoring of the QE of photocathodes produced up to 7 years ago has not shown any measurable degradation when care is taken to avoid all contacts with air [7].

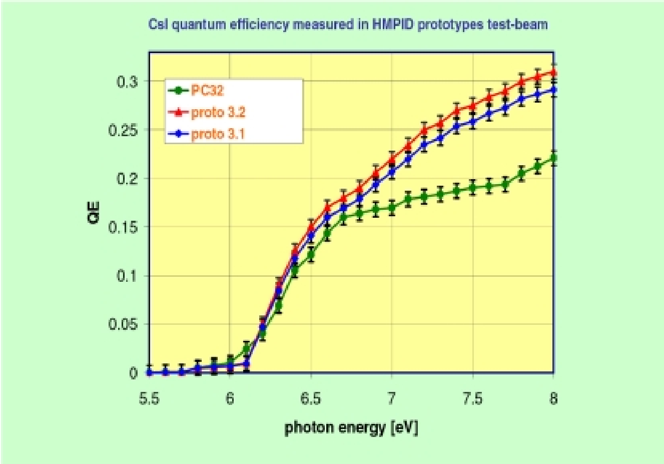

Fig. 2. PCs QE from test beam measurement

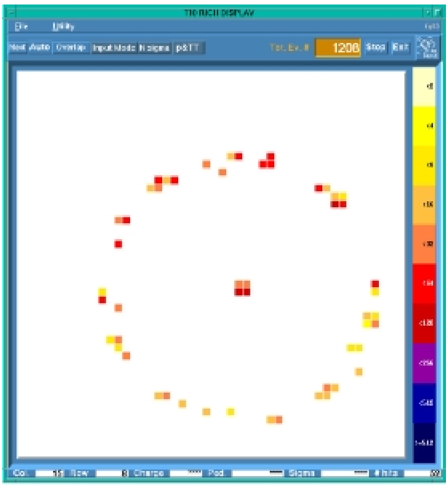

Fig. 3. Cherenkov event (test beam data)

4 Detector prototype ("Proto-2")

The so-called Proto-2 is a 2/3 scale prototype of one HMPID module, it accepts 4 PCs for a total CsI area of $\sim$1 m^2. The radiator is made of 2 independent trays of size 133×41 cm^2. The perfluorohexane thickness is 10 mm. A total of 15360 pads are read out using the ASIC GASSIPLEX 1.5 chip [8].

A full technical description and performance report can be found in [1,2,3,5].

At the end of 1999 Proto-2 has been installed in the STAR experiment [4] at BNL. Since then it is taking data in Au–Au and p–p collisions, being the first proximity-focusing CsI-based RICH detector used in a collider experiment.

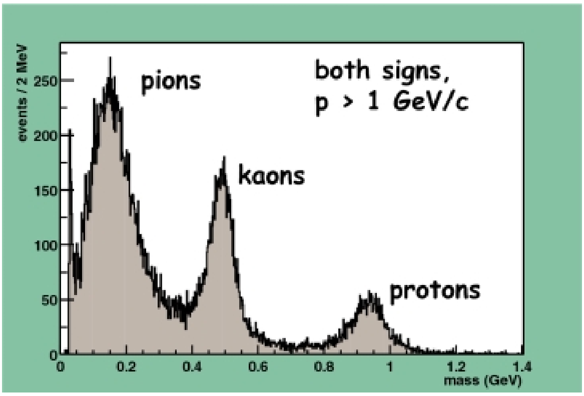

Fig. 4. Mass measurement with Proto-2 in STAR

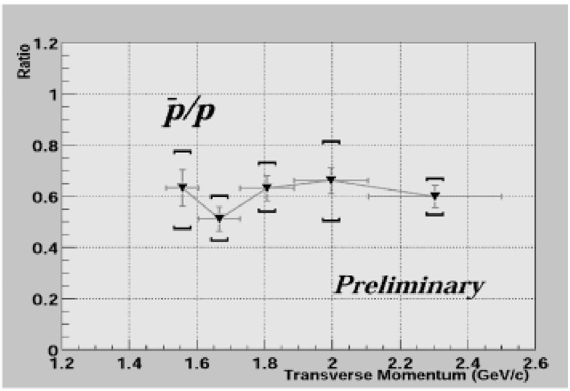

Fig. 5. Antiproton/proton ratio measured in STAR

Figure 4 shows a mass spectrum obtained with a sample of about 300 k events ($\sim$1/3 of the total statistics) collected during the inaugural RHIC run in the year 2000; Fig. 5 shows the preliminary measurement (300 K events) of the antiproton/proton ratio in Au–Au central collisions at $\sqrt{s_{NN}} = 130$ GeV [9]. This result is in agreement with the results presented by PHENIX [10]. The measurement upper limit (2.3 GeV/c) is given by the available statistics. More than 4×10^6 central events have been collected in 2001 and are at present under analysis.

The number of dead or missing channels, after two years running at RHIC, is 30 (0.002%) and has not been changing from the beginning. This number also includes missing or bad connections in the full readout chain.

5 The GASSIPLEX and DILOGIC chips

Two dedicated ASIC chips have been developed in the framework of the HMPID project.

Table 1.

Technology	ALCATEL-MIETEC 0.7
Silicon Area	13.8 mm^2
VDD/VSS	±2.8 V
Noise	530 e^- r.m.s. 0 pF
Noise slope	11.2 e^- r.m.s./pF
Linear Dynamic Range	>500 fC
Conversion gain	3.6 mV/fC
Base line recovery	<0.5% after 5 μsec
Peaking time	1.1–1.3 μsec
Power consumption	128 mW/chip
Analogue readout speed	10 MHz max.
Package	QFP44L or TQFP48L

In the HMPID application the GASSIPLEX analogue output will be presented to the input of a commercial 12-bit ADC (AD9220ARS) followed by the DILOGIC chip. Data are then readout via the standard ALICE optical link (DDL) [13].

The GASSIPLEX-0.7 [11] chip is a 16-channel analogue multiplexed low noise signal processor working in TRACK&HOLD mode. It features a dedicated filter to compensate for the long ion drift tail, a semi-gaussian shaper and internal protection against discharges. Up to 60 chips can be run in daisy-chain mode, greatly reducing the number of the needed ADCs. Table 1 lists the main chip characteristics. The noise on detector is found to be ∼1000 e^- r.m.s.

The full GASSIPLEX production required for the HMPID detector (∼13000 chips including spares, QFP44L package) is already available and under test. Results on a sample of 2500 chips show a yield greater than 95%.

The DILOGIC chip [12], designed in the ALCATEL-MIETEC 0.7 technology, is a sparse data scan readout processor providing zero suppression and pedestal subtraction with individual threshold and pedestal values for up to 64 channels. Several chips can be daisy-chained on the same 18-bit (12-bit pulse height + 6-bit address) output bus. The power consumption is 60 mW for a read/write speed of 20 MHz. Asynchronous read/write operations are allowed.

6 Conclusions

In the frameworks of the RD26 and ALICE/HMPID collaborations a technology to produce large CsI PCs with high QE and reproducibility has been developed. If kept under inert gas flow, the PCs have a QE stable over several years and up to a local integrated charge density of ∼1 mC/cm^2.

A detector built as prototype for the ALICE/HMPID and installed in the STAR experiment at RHIC is delivering physics results thus proving the chosen technology and design to be adequate for ALICE.

Two ASIC chips have been developed and qualified for the ALICE/HMPID front-end electronics.

Finally the project fully entered the production phase with the assembly of the first detector module, started December 2001.

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References

1. ALICE collaboration, Technical Design Report of the High Momentum Particle Identification Detector, CERN/LHCC 98-19
2. F. Piuz et al., Nucl. Instr. and Meth. A 433 (1999) 222–234
3. A. Di Mauro et al., Nucl. Instr. and Meth. A 433 (1999) 190–200
4. STAR-RICH collaboration, Proposal for a Ring Imaging Cherenkov detector in STAR, YRHI 98-012
5. F. Piuz et al., Nucl. Instr. and Meth. A 433 (1999) 178–189
6. E. Schyns et al., Nucl. Instr. and Meth. A 461 (2001) 584–586
7. A. Di Mauro et al., “Aging of large area CsI photocathodes for the ALICE HMPID detector”, presented at the Aging Phenomena in Gaseous Detectors Conference, Hamburg 2001, to be published
8. J.C. Santiard et al., ”GASPLEX, a low noise analog signal processor for readout of gaseous detectors”, CERN-ECP 94-17
9. D. Cozza et al., STAR and STARRICH Collaboration, Proceedings of “QCD@WORK. International Workshop on Quantum Chromodynamics: Theory and Experiment”, Martina Franca, Bari, Italy, 16–20 Jun 2001, published on AIP Conference Proceedings, vol. 602
10. H. Ohnishi et al., PHENIX Collaboration, Proceedings of “ 15th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions”, Stony Brook, NY, USA, 15–20 Jan 2001
11. J.C. Santiard et al.,”The GASSIPLEX07-2 integrated front-end analog processor for the HMPID and Dimuon spectrometer of ALICE”, proceedings of the 5th Conference on Electronics for LHC experiments, Snowmass, CO, USA, 20–24 Sep. 1999
12. J.C. Santiard et al.,”DILOGIC-2 a sparse data scan readout processor for the HMPID detector of ALICE”, proceedings of the 6th Conference on Electronics for LHC experiments, Cracow, Poland, 11–15 Sep. 2000
13. G. Rubin et al., “ALICE Detector Data Link (DDL)”, Internal note ALICE 98-21