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Experience from the construction and installation of the HMPID CsI-RICH detector in ALICE

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Abstract

The construction and installation phases of the High Momentum Particle IDentification (HMPID) detector of the ALICE experiment were completed by summer 2006. The total active area of the detector is 11 m^2. It represents the largest scale application of CsI photo-cathodes in RICH detectors to date. We will report on the production of the CsI photo-cathodes, the readout electronics, the Multi-wire Proportional Chambers (MWPCs) and the assembly and handling procedures needed to produce such a large detector.

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1. Introduction

The ALICE High Momentum Particle IDentification (HMPID) detector [1,2] is a proximity focusing RICH, devoted to the identification of charged pions and kaons in the range of $1<p_t<3\,\mathrm{GeV}/c$ and protons in the range $2<p_t<5\,\mathrm{GeV}/c$. The total active area is 11 m^2 shared between seven identical modules that use CsI photo-cathodes (PCs) with high quantum efficiencies (QE) to detect UV Cherenkov light from liquid C_6F_{14} radiators. These PCs are operated at atmospheric pressure inside a Multi-Wire Proportional Chamber (MWPC) filled with CH_4, they are segmented into pads, and coated with a 300 nm photosensitive layer of CsI. The sensitive gap of the MWPC is 4.45 mm, the cathodes are grounded and a voltage of +2050 V is applied to the anode wire plane providing a total gas gain of 5×10^4. The analogue signal induced in the pads is read out individually and measures the position of the Cherenkov photons of the ring.

2. MWPC assembly

The detector is constructed by stacking three independent aluminum frames (1.5×1.5 m), in such a way that simple machining ensures [1,2]:

- the parallelism and a controlled thickness of the anode-to-cathode gaps of the MWPC, both within ±50 μm;
- installation/removal of PCs in a simple procedure from the outside without affecting the MWPC geometry;
- the parallelism between the radiator trays and the photodetector (±200 μm);

The sealing is achieved by soft O-rings (FKM 75) placed in grooves between the frames. The first frame holds the six PCs and the anode wire plane. The anode–cathode (PC) gap is 2 mm. The 20 μm thick gold plated W-Re anode wires, spaced 4.2 mm apart, are soldered on a G10 printed circuit board with a tension of 46 ± 1 g. The second frame holds two wire planes. One of the wire planes is the second cathode plane of the MWPC, placed 2.45 mm above the anode plane. It is made of 100 μm thick gold plated Cu–Be wires, with a pitch of 2.1 mm, and stretched at 210 ± 5 g using crimping pins. The second wire plane in this frame is

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the collection electrode, placed close to the radiator vessel exit window. It is made of 100 μm diameter gold plated Cu–Be wires with a pitch of 5 mm, at a tension of 55 ± 1.5 g. This wire plane is positive biased (400 V) to prevent electrons released by charged particles in the proximity gap from reaching the MWPC. All the wire tensioning and measurement have been done at 23 °C, which will be approximately the temperature at which the detector will be operated. A stiff and light composite panel made of Rohacell (50 mm) between two thin layers (0.5 mm) of aluminum is fixed on the third frame to close the detector.

3. Procedure for PC production and quality monitoring

The PC production procedure has been published in Ref. [3]. The use of the VUV-scanner [4], providing immediate feedback on the quality of the PCs, allowed a fine tuning of the whole process obtaining the best results. In the following we described the basic steps of the procedure and the quality monitoring after the coating.

The substrate for the CsI PCs is a double layer Cu clad PCB, coated with Ni and Au and segmented into pads ($8 \times 8.4\,\mathrm{mm}^2$). After the assembly the substrate undergoes a series of very strict quality tests and multiple cleaning procedures [3]. The PC is installed in the evaporation plant [1,4], the CsI deposition is carried out at 60 °C and a pressure of approximately 6×10^{-7} mbar. The evaporation rate is kept at ≈ 1 nm/s, the final layer thickness achieved is 300–325 nm.

Immediately after the CsI deposition, the PC is transferred to the VUV-scanner integrated in the chamber. The VUV-scanner allows an in situ scan of the photo-current across the whole PC surface [4]. The PC is kept under vacuum at 60 °C for several hours, heat treatment, to improve the response and achieve the final QE [3]. Afterwards, the system is cooled down to room temperature to perform the final 2D mapping of the photo-current before the extraction of the PC from the evaporation plant in a sealed protective box, filled with Ar gas to avoid any contact of the highly hygroscopic CsI layer with humid air. The enclosed PC is connected to Ar flow until the definitive installation in the detector modules. This installation is done using a customized glove box that fits one detector module.

During the final 2D mapping with a UV light beam the photo-current from the PC is recorded as well as a reference signal from a CsI photomultiplier for normalization [4]. The average normalized current $\langle I_{\mathrm{norm}} \rangle$ of the 280-point mappings is used to compare the PC quality. The lower level for acceptance was derived from a comparison of the scans of the first 17 PCs with test beam results as described in Ref. [3]. The PCs with $\langle I_{\mathrm{norm}} \rangle = 3$ provide a minimum of 16 resolved clusters per Cherenkov ring in the beam tests which is sufficient to achieve the required detector performance [5].

4. Liquid circulation system and radiator vessels

In this section we describe briefly the radiator vessels and the liquid circulation system (LCS) [1,6]. Each HMPID module is equipped with three liquid radiator vessels of $1330 \times 413 \times 15\,\mathrm{mm}^3$ made of a glass–ceramic material (NEOCERAM®) and fused silica (SiO_2) plates used as UV-transparent windows. To withstand the hydrostatic pressure, 30 cylindrical spacers (10 mm diameter) are glued to the NEOCERAM plate on one side, and to the quartz window in the other side.

During the assembly, an optical table was used to ensure the right flatness over the whole surface of the radiators. All the gluing is performed with a custom-made tool that ensures a glue thickness of 0.15 mm everywhere. Before the production of the final radiator vessels, a full-scale prototype vessel was built and tested in several hydrostatic conditions. An overloading test with 140 mbar above atmospheric pressure was successfully performed. The 30 spacer configuration guarantees a safety coefficient of seven under maximum constraints.

The LCS is required to purify, fill, recirculate and empty the 21 radiator vessels independently, remotely and safely. The high density of the C_6F_{14} (1.68 g/cm^3 at 20 °C) causes considerable hydrostatic load. Therefore, the liquid distribution to and from the radiators is based on a gravity flow principle, to avoid any accidental hydrostatic overpressures. In addition, the C_6F_{14} is very volatile and with high solubility of oxygen and water vapor on it. To fix these problems a gas reference line in which anhydrous argon is continuously flushed has been implemented in all the volumes above the liquid. This gas line is maintained at some millibar over the atmospheric pressure by using a oil bubbler, blocking the entrance of air in the system. The argon is exhausted through a cold trap that removes the liquid vapors from the gas. Furthermore, a dedicated filtering station was built to remove from the liquid all the contaminants that spoils the UV transparency (mainly water and oxygen). The implementation of the LCS in the ALICE experiment can be divided in three distinct units [6]:

- the pumping station located outside the ALICE solenoid magnet;
- the distribution station located close to the HMPID detector inside the ALICE solenoid magnet, ~9 m above the pumping station;
- The filling and purifying station, located in the radiation shielded plug 32 m above the pumping station.

The liquid is continuously pumped from the pumping station to the filling and purifying station. A fraction of the liquid goes into the purifier, the other one flows, by gravity into the distribution station at a constant rate. The excess flow comes back to the pumping station through an overflow to be pumped again. The distribution station has been designed to control the flow rate into the radiator vessels as well the hydrostatic pressure that can be applied to each vessel. Once the vessels are filled then the liquid goes back to the pumping station, where the cycle restarts. The three stations are connected by liquid C_6F_{14} pipes and by the above-mentioned reference gas line that equalizes the pressure in all the parts of the system. The system has been designed in such a way that the parts and maintenances services that require frequent interventions, like filter changes, addition of new liquid or transparency monitoring are located outside the experimental area.

5. Readout electronics

The task of the HMPID readout electronics is to measure the analogue signal induced on the pads of the MWPC cathode plane. The characteristics of the detector as well as physics requirements demand to have at the same time a low noise, a large dynamic range and highly segmented readout electronics. To fulfill the above conditions, two dedicated ASICs have been specifically developed: the Gassiplex07-3 and the Dilogic-3 [7]. The Gassiplex07-3 is a 16-channels multiplexed analogue low noise signal processor. The Dilogic-3 is a sparse data scan digital processor that performs the zero suppression and the pedestal subtraction. All the chips needed to read out the seven HMPID modules (10080 Gassiplex and 3360 Dilogic) were mounted on cards and tested. During test beam validation of the modules, as well as during the integration of the modules in the experiment, several noise measurements of the electronics on the detector have been made. The average on-detector noise measured for 10080 chips is less than $1000e^-$ with a dispersion in the measurement less than $50e^-$. These noise measurements have shown that there are 196 noisy/dead channels out of 161 280 (0.12%).

6. Detector control system

The HMPID Detector Control System (DCS) is intended to ensure a safe and synchronized operation of the following subsystems [8]:

- low voltage (LV) to power the readout electronics;
- high voltage (HV) for the MWPCs;
- the readout electronics cooling;
- the C_6F_{14} LCS;
- the gas system for the MWPCs;
- The physical parameter monitoring system (pressures, temperatures and C_6F_{14} transparency).

The Finite State Machine (FSM) technique has been extensively used in the modeling of the DCS and subsystem controls. The FSM approach provides the DCS automation, its partitioning and various modes of operation that make easier the integration or exclusion of any particular subsystem from the HMPID DCS. If needed the exclusion of the whole HMPID DCS can be done from the Experiment Control System (ECS). This feature allows the operation of either the whole detector or a single subsystem in one of the following modes: debugging, calibration, automatic or manual operation. The HMPID DCS, either at the highest hierarchical level, or at the single

Fig. 1. HMPID detector on the cradle before the installation inside the ALICE solenoidal magnet.

subsystem control, contains a certain level of automation. When the user issues a command, the control executes a series of operations according to a predefined sequence that prevents or reduce the possibility of operational mistakes. The HMPID DCS implementation was done in the PVSS v.3.6 SCADA[1] environment used at CERN [9], the modeling of the DCS and the subsystem controls as FSMs is performed using the SMI++ software tool developed at CERN [10], being everything embedded in the JCOP-Framework (FW v.3.0.0) [11].

7. Detector performance and test beams

During the construction phase each HMPID module undergoes several quality and performance checks. After the assembly, critical parameters like gaps in the MWPC, planarity, wire tension, etc. are rechecked to meet the design specifications. Afterwards, the gas leak rate is measured.

The HV commissioning of the module is performed with different gases (CO_2 and CH_4), at different voltages (1950–2100 V) and for different periods of time (up to weeks). The dark current in each of the six HV sectors should be less than 0.2 nA. Finally, we performed a gain mapping of the whole detector using a ^{90}Sr source. After all the above tests in the laboratory the module is commissioned in the test beam. The MWPC is studied in terms of operation stability (HV, rate, electronic noise) and gain uniformity. The test beam was also used to cross-check and validate the results from the VUV-scanner, which has been employed to set the acceptance level during the mass production of the PCs [3,4]. Five out of seven modules have been tested in CERN/SPS-X5 area with a 120 GeV/c π^- beam [5]. Modules 6–7 were commissioned in 2006 with cosmic rays, due to the non-availability of test beams at CERN during 2005. A preliminary analysis has shown that the modules are performing as expected.

8. Conclusions

The HMPID module production, quality assurance and installation finished successfully in September 2006, see Fig. 1. It represents the largest scale application of CsI PC technology in RICH detectors to date. The seven modules have shown either in test beam operation or in the cosmic ray test a performance better than the design specifications. The commission of the ancillary subsystems is well advanced. It is expected to have the detector fully commissioned by July 2007 well before the startup of the LHC pp pilot run.

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[1]Slow Control and Data Acquisition system.