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COMPASS RICH-1

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Abstract

RICH-1 is one of the key detectors of the COMPASS experiment at CERN. It is a large acceptance gaseous RICH, designed to perform π/κ separation up to 60 GeV/c. All RICH-1 components are built, most of them have been commissioned during year 2000 COMPASS technical run and the detector will be completed during Spring 2001. We give a description of the detector and report about various technological achievements required by this challenging project. © 2002 Published by Elsevier Science B.V.

1. Introduction

The COMPASS [1] experiment at CERN SPS is devoted to the study of the spin structure of the nucleon with polarised semi-inclusive DIS measurements using the SPS muon beam and the study of hadron spectroscopy. Technically, the most challenging requirements of this Physics programme are large integrated luminosities and hadron identification in crowded environments. Thus, RICH-1 is one of the key detectors of the experiment.

In the following, the detector is described and the status of the different components together with some technological achievements are presented.

2. RICH-1 design, specifications and description

The major requirements for RICH-1 design related to the general design of the experiment are

- the capability to separate π and K with momenta up to $\sim$60 GeV/c in a high-intensity environment,

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- the full acceptance of the large-angle spectrometer (horizontal: ± 250 mrad; vertical: ± 200 mrad),
- to minimise the total amount of material (RICH-1 is followed by electromagnetic and hadronic calorimeters and by the small-angle spectrometer),
- the capability to register and handle high data fluxes.

These considerations have suggested the basic design parameters of RICH-1 [2] (Fig. 1) shortly presented here.

It is a gas RICH with 3 m long C_4F_{10} radiator at atmospheric pressure, maintained at 25° to obtain uniform temperature in the radiator volume. To ensure transmittance higher than 80% for 165 nm photons with a typical path in the radiator medium of 4.5 m, limited contamination from UV absorbing impurities are required (goal: water vapour and oxygen traces <5 ppm); they are removed with molecular sieves. C_4F_{10} and N_2 separation is obtained with a liquifier. The gas flow is $\sim 10\,m^3/h$. For the vessel ($\sim 80\,m^3$), leakages $<10^{-2}$ mbar l/s and non polluting materials are required. The front and rear vessel windows (covering the spectrometer acceptance region) are sandwiches of two thin Al foils and a layer of rigid foam, resulting in $\sim 2\%$ of radiation length per window. The surface of the largest composite panel is $>20\,m^2$.

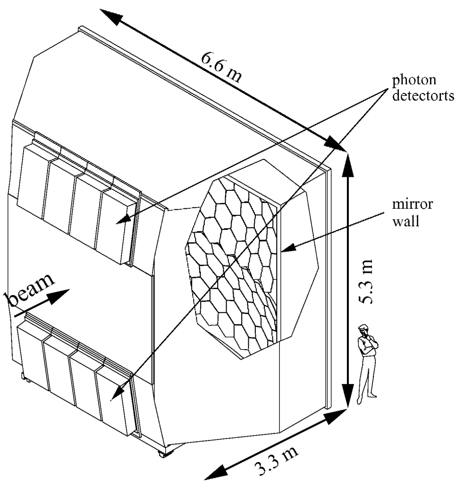

Fig. 1. Artistic view of COMPASS RICH-1.

The mirror system consists of spherical mirrors, radius 6.6 m, segmented in 116 hexagonal and pentagonal pieces covering a total area $>20\,m^2$, forming two spherical surfaces focalising the Cherenkov photons onto two sets of phodetectors placed above and below the acceptance region. The local deviation of the mirror shape from the spherical one must not exceed $\sigma_\theta = 0.2$ mrad and the deviation of the radius of the single mirrors from the nominal value must be at most $\sigma_R/R = 0.5\%$. The mirror substrate cannot exceed 5.5% of radiation length, corresponding to 7 mm of borosilicate glass. Reflectance $>80\%$ down to 165 nm and good surface roughness (r.m.s. ~ 1.6 nm) are required. The mirror supporting mechanical structure with individual angular regulation of the mirror pieces (with ~ 0.2 mrad resolution), must also be light and, at the same time, extremely rigid. In the resulting design (2), the equivalent amount of material in the spectrometer acceptance is $\sim 2.5\%$ of radiation length. The rigidity of the structure together with that of the RICH vessel (the mirror wall is fixed onto the vessel) has been studied with FEM calculations (Fig. 2).

Taking into account the large area to be instrumented with photon detectors ($5.3\,m^2$), we have chosen MWPCs with segmented CsI photocathodes, the UV photon detectors developed in the context of RD26 [3] and, later, for the ALICE HMPID project [4], that have also been chosen for several other projects [5]. RICH 1 will be equipped with eight identical chambers, each one having an active surface of $576 \times 1152\,mm^2$ (Fig. 3). The photocathode planes are formed by two $576 \times 576\,mm^2$ double-layer PCBs. The fused silica (quartz) windows are formed by two identical fused silica plates ($600 \times 600 \times 5\,mm^3$). Great care is devoted to the handling of the PCBs with CsI layer to ensure that they are never exposed to atmospheres with more than 100 ppm air contamination. Detail about photon detector design and construction, CsI handling and tests of the small and full size prototypes can be found in Ref. [2].

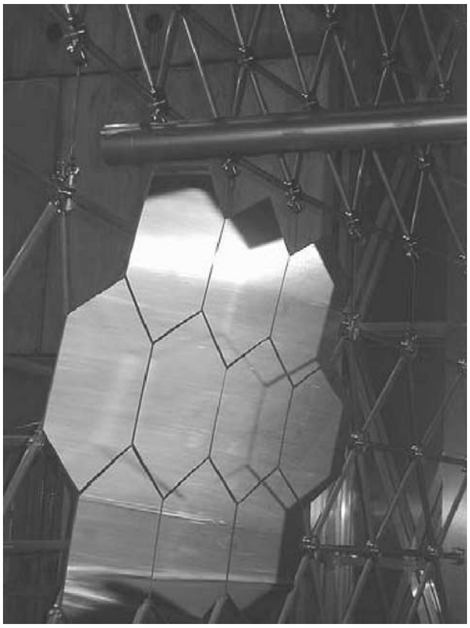

Fig. 2. Ten mirror pieces installed in RICH-1 in year 2000. The mechanical arrangement of the mirror wall is also visible.

Fig. 3. Four CsI photon detectors assembled on a single panel being mounted onto RICH-1 vessel in Spring 2000.

The pixel segmentation of the photocathodes (pixel size: $8 \times 8\,mm^2$) results in about 80 000 channels equipped with analogic readout electronics (mainly needed to obtain good efficiency); the expected occupancy level is $\sim 5\%$ resulting (at maximum trigger rate of $10^5/s$) in a total maximum data flow of 2.5 Gbyte/s during SPS spill. The heart of the read-out system [6] are the large front-end BORA boards, housing the front-end chip and local intelligence (FPGA: XILINX VIRTEX XCV100-5PQ240C[2] DSP: ADSP-21065KLS240[3]) for logic control of front-end stage and data pre-reduction. BORAs are controlled via eight parallel networks of DSPs through a PC–PCI dedicated interface designed for this read-out system: DOLINA board.

3. Relevant technological achievements

RICH-1 vessel has been installed in COMPASS experimental hall during Spring 2000. Its tightness has been checked flushing with pure N_2 at $\sim 10\,m^3/h$ and the measured O_2 contamination level is ~ 5 ppm, fulfilling design figure.

Radiator gas system has been installed and commissioned during year 2000. Exercises of filling (N_2 replaced by C_4F_{10}) and emptying (C_4F_{10} replaced by N_2) indicate that, for both operations, gas replacement at 97% level can be performed. More precise determination of residual gas fractions are taking place.

C_4F_{10} (1.5 t) has been bought from 3M.[4] A dedicated system to recirculate in a closed loop and filter C_4F_{10} in liquid phase has been built. Samples of the liquid can fill on line a 5 cm long cell equipped with CaF_2 windows for transmission measurements. The cell is inserted in the measurement section of a device for UV transmission measurements, which has been obtained upgrading the CERN reflectometer designed and built for the DELPHI experiment [7] adding a new dedicated chamber. Fig. 4 presents a typical transmission curve after cleaning procedure, compared with the transmission of the raw material. C_4F_{10} bottles groups in two categories approximately equally populated according to our experience: (i) easy to clean using Cu Catalyst BASF R3-11[5], losing $\sim 5\%$ of the material and (ii) difficult to clean; for

[2] VIRTEX XCV100-5PQ240C XILINX by XILINX, Inc., San Jose, CA, USA.

[3] ADSP-21065KLS240 by Analog Devices, Inc., Norwood, MA, USA.

[4] 3M performance fluid PF-5040 by Minnesota Mining and Manufacturing Company, 3M Center, St. Paul, MN, USA.

[5] BASF Catalyst R3-11 by Badische Anilin & Soda Fabrik AG, Ludwigshafen, Germany.

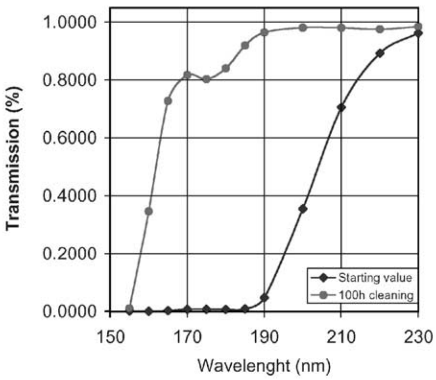

Fig. 4. UV light transmission through 5 m of C_4F_{10} in gas phase at atmospheric pressure for raw material and after pre-cleaning. The data are obtained scaling from measurements in liquid phase through 51 mm, corresponding to $\sim$7 m of gas at atmospheric pressure.

the latter samples, the optimisation of the filtering material is still ongoing and thus the overall material losses have to be defined ($\sim$50% with Cu Catalyst). Small samples of C_4F_{10} from the (ii) category bottles have, in any case, been cleaned indicating the feasibility of the cleaning procedure.

The same facility for UV transmission measurements has been used to determine the transmission of the large quartz plates, that form the UV windows of the photon detectors. The large size of the measuring chamber makes possible to perform measurements in several location on the plate surface. The quartz plate cut-off is at about 165 nm, according to specifications.

In year 2000, 125 mirror pieces (including a few spare pieces) have been produced: their optical and reflectance parameters (measured for each individual piece) satisfy the specifications; in particular, optical parameters are, on average, largely better than specifications, demonstrating the feasibility of good quality mirrors with thin glass substrates (see also [8]). Ten mirror pieces (a pre-series production) have been mounted in RICH-1 during Spring 2000 (Fig. 2). This exercise has allowed to test the rigidity of the supporting mechanical arrangement (mirror supports and vessel), the resolution of the alignment device and the overall procedure of the angular mirror alignment. Accuracies according to specifications ($\sim$0.2 mrad) have been obtained. Repeated measurements performed after some days confirm the results indicating that the mechanical rigidity of the system is according to needs.

4. Conclusion and perspectives

The status of the various RICH-1 components is quite advanced and the performances of the different elements look according to specifications. RICH-1 will be completed during Spring 2001 and will be in operation for the year 2001 run of the COMPASS experiment.

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