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The COMPASS RICH project

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Abstract

The set-up of the COMPASS experiment (NA58 at CERN SPS) consists of two spectrometers (a large-angle one followed by a small-angle spectrometer) both equipped with a gas RICH (RICH 1 and RICH 2) for hadron identification. RICH 1 is currently under construction, while RICH 2 will be added at a second stage. RICH 1 design parameters and technological choices are discussed.

1. Introduction

COMPASS [1] is a fixed-target experiment at CERN SPS with a rich physics programme including measurements of semi-inclusive and inclusive polarized deep inelastic scattering (with the SPS polarized muon beam and polarized hydrogen and deuterium targets) and hadron spectroscopy studies, in particular charm production, search for exotics in high quark spectroscopy and Primakov reactions (with hadron beams). In particular, the measurement of the gluon contribution to the nucleon spin ($\Delta G/G$), from open charm leptoproduction is one of the major goals of the experiment and one of the first measurements that will be performed.

First beam for setting-up is foreseen in the year 2000 and the physics measurements will start at the end of the same year or in 2001.

The most challenging requirements of this physics programme are large integrated luminosities (large beam intensities, reduced dead time and high data rates) and hadron identification. The apparatus consists of two consecutive spectrometers (the large-angle and the small-angle spectrometers) both equipped with a RICH detector: RICH 1 and RICH 2. During the first stage of the experiment, part of the set-up will not be instrumented and RICH 2 will not be present. RICH 1, currently under construction, is discussed in this paper.

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2. RICH 1 general design

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 ∼ 60 GeV/c in a high-intensity environment;
- the full acceptance of the large-angle spectrometer (horizontal: ± 250 mrad; vertical: ± 200 mrad);
- to minimize the total amount of material (RICH 1 is followed by electromagnetic and hadronic calorimeters and by the small-angle spectrometer).

A non-minor constraint is the request to match the compressed time schedule of the experiment.

These considerations have suggested the basic design parameters of RICH 1 (see Fig. 1).

It is a gas RICH with 3 m long C_4F_{10} radiator at atmospheric pressure, maintained at 25°. The mirror set-up consists of spherical mirrors, radius 6.6 m, segmented in 120 hexagonal pieces covering a total area larger than 20 m^2, forming two spherical surfaces with different centres of curvature so as to focalize the Cherenkov photons onto two sets of photon detectors placed above and below the acceptance region; good reflectance down to ∼ 165 nm is required. (More about RICH 1 optics can be found in Ref. [2].) The photon detectors are MWPCs equipped with CsI photocathodes for a total active surface of 5.3 m^2. The pixel segmentation of the photocathodes (pixel size: 8 × 8 mm^2) results in about 80 000 channels equipped with analog readout electronics (mainly needed to obtain good efficiency); the expected occupancy level is ∼ 5% resulting (at maximum trigger rate of 10^5 s^{-1}) in a total maximum data flow of 2.5 Gbyte/s during SPS spill.

3. The photon detectors

Taking into account the construction schedule for RICH 1, the large area to be instrumented with photon detectors and the available resources, 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 [4,17]. The basic detector geometry corresponds to the RD26 standard parameters (anode wire diameter, 20 μm; anode wire pitch, 4 mm; anode-cathode gaps, 2 mm,

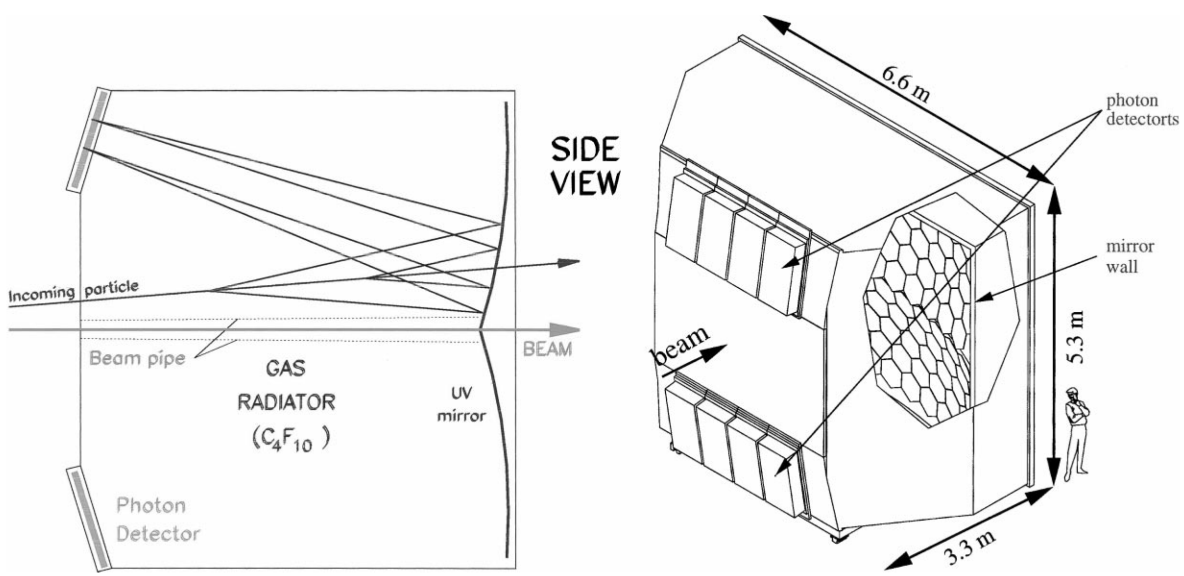

Fig. 1. COMPASS RICH 1: Principle scheme and artistic view.

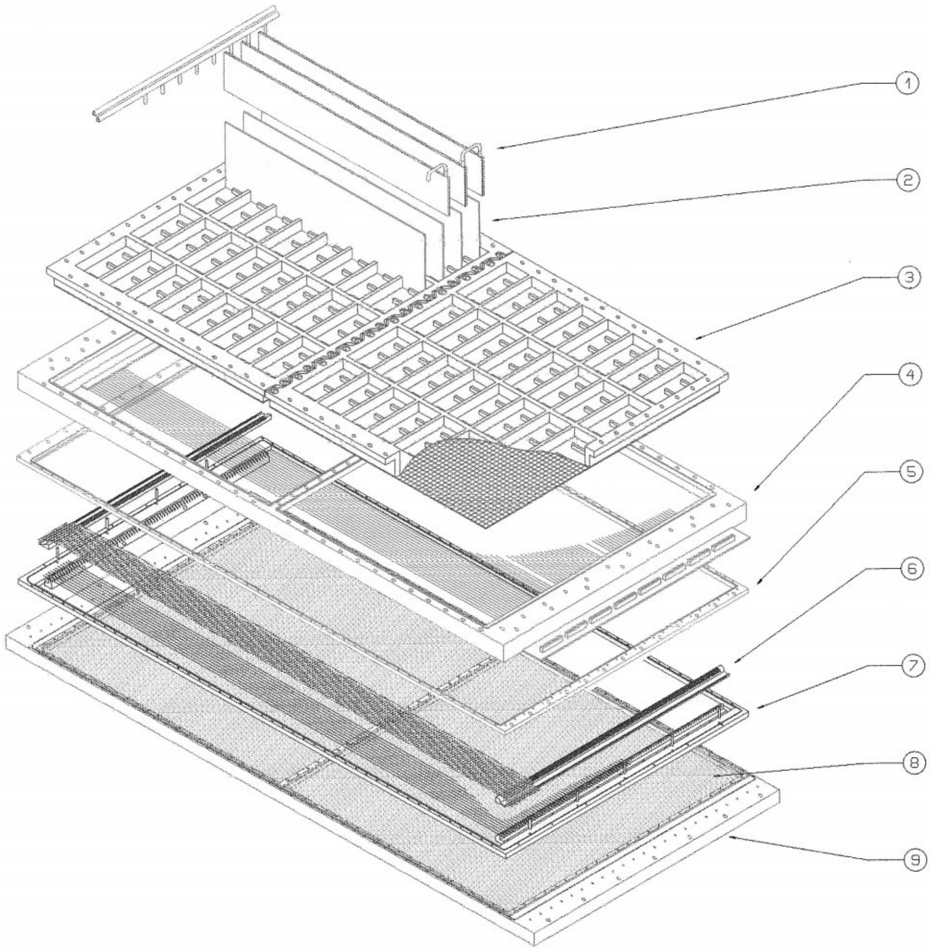

Fig. 2. One of the photon detectors of COMPASS RICH 1: (1) cooling plates, (2) readout boards, (3) CsI photocathode boards, (4) anode wires, (5) distance frame, (6) cathode wires, (7) collection wires, (8) fused silica plates, (9) fused silica frame.

symmetric; cathode wire diameter, 100 μm; cathode pad size, 8×8 mm^2; collection wire plane to avoid charge accumulation outside active volume).

RICH 1 will be equipped with 8 identical chambers (Fig. 2), each one have an active surface of 576×1152 mm^2. The photocathode planes are formed by two 576×576 mm^2 double-layer PCBs. Anode wires, 1260 mm long, are supported at mid length by insulating MACOR [5] bars. The fused silica (quartz) windows are formed by 2 identical fused silica plates ($600 \times 600 \times 5$ mm^3) glued onto Al frames via an intermediate FPM 75 frame. Gas tightness is obtained with FPM 75 O-rings. The use of nonmetallic materials has been minimized in the design. The Alcoa Alca Plus Al alloy [6] is used for all the chamber frames.

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: We have built a cathode PCB transport system with closed circulation of filtered N_2 and dedicated glove boxes for assembling and for maintenance interventions.

During detector construction, all mechanical parameters are checked and, when necessary, corrected by hand. The goal is to keep anode cathode gaps at nominal value ± 50 μm and wire tension at nominal value $\pm 5\%$.

Starting in 1996, we have tested a small-size prototype of MWPC with CsI photocathode (20×20 cm^2), a full-size prototype and the first of the 8 final chambers. All the tested chambers are electrically very stable and exhibit dark current < 10 nA up to at least 200 V above the working HV value. Gas tightness is also good (O_2 level < 10 ppm fluxing the chambers at the rate of one volume per hour). The effective quantum efficiency of the 5 photocathodes has been measured in the RD26/ALICE set-up with proximity focusing geometry and 10 mm C_6F_{14} radiator, and it is similar to the values measured by RD26 and ALICE [4]: effective quantum efficiency at 170 nm ranges between 0.16 and 0.24.

4. The readout electronics system

The front-end element is a modified version of the GASSIPLEX chip [7] developed for RD26: it includes preamplifier, shaper, and analog multiplexer stages. The main modifications concern the reduced dead time which, for the COMPASS-GASSIPLEX, is 400 ns per event.

The front-end chip is integrated in a powerful front-end card (BORA board) which reads 432 channels and digitizes the information (ADCs: AD 9201ARS [8]). FIFOs (CY7C4235-10 [9]) decouple the front-end stage and the logic stage to avoid increasing the intrinsic COMPASS-GASSIPLEX dead time. Logic operations on data (pedestal subtraction, threshold comparison, zero suppression) are performed by an FPGA (XILINX SPARTAN CY30CS40XLFQ208C [10]), which also provides the logic sequencer of the front-end stage. A powerful DSP (ADSP-21065KLS240 [11]) performs event framing and on-board controls (low voltage levels, temperature monitoring, pedestal measurements, calibration and testing). Digitized data are transferred to the acquisition system via optical links (one per board). In the front-end card, each event is processed in < 10 μs. The Bora boards are mounted directly onto the rear side of the photocathode PCB planes. (More details can be found in Ref. [12].)

5. The gas radiator and the radiator vessel

The major request concerning the radiator gas is its purity, in particular the limited contamination from impurities that can absorb UV photons: the goal is water vapour and oxygen traces smaller than 5 ppm. These figures result in requirements concerning the gas system and the vessel design.

RICH 1 gas system follows the HERA-B design and choice of components [13]; H_2O and O_2 are removed using molecular sieves and C_4F_{10} and N_2 separation is obtained with a liquifier. The gas flow is one volume (~ 80 m^3) every 8 h.

For the vessel, we require very severe figures for the gas tightness (leakages $< 10^{-2}$ mbar l/s) and nonpolluting materials.

The vessel must be thermalized to limit the refractive index dispersion: with $\delta T < \pm 1^\circ$, $\Delta n/(1-n) < \pm 0.4\%$, to be compared with chromatic dispersion contribution ($\pm 1.2\%$ assuming chromatic dispersion from Ref. [14]) and contribution from hydrostatic pressure ($\pm 0.25\%$).

The vessel is designed to be not only the radiator-gas tank, but also the support for the mirror wall (which is fixed inside the vessel onto the rear vessel frame) and for the photon detectors, mounted onto the front vessel frame. The design criteria take into account both the requirements related to gas purity and the rigidity and stability (at fixed temperature) needed to guarantee the relative alignment of mirrors and photon detectors. The main characteristics are as follows.

- The vessel is an extremely rigid Al autosupporting box: the rigidity of the structure has been studied with FEM calculation. The interface frames between vessel structure and mirror wall, photon detector, front and rear windows are machined.
- The front and rear windows (covering the spectrometer acceptance region) are sandwiches of two Al foils (thickness 0.5 mm) and a layer of Rohacell foam [15] (thickness 50 mm), reduced to one single Al foil in the beam region.
- Expanded PTFE gasket is used to ensure vessel gas tightness.

6. The mirrors

The main requests for the mirrors concern performances in the UV region, surface shape and amount of material. Among the proven technologies, the second set of mirrors produced for the OMEGA RICH [16,18] are the best suited for RICH 1 application, and the design of the RICH 1 mirrors follows the OMEGA design. The substrate is a sandwich of two float glass layers (2 mm thick) and glass foam (5 cm thick), for a total equivalent thickness of about 7 mm of glass. The measured Young's modulus is 0.014×10^5 MPa. Good reflectance in the far UV region is obtained with a reflective coating of Al (80 nm) protected by a layer of MgF_2 (30 nm). Good surface roughness (r.m.s. $\sim$ 1.6 nm) is required. The local deviation of the 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 $\sigma_R/R = 0.5\%$ (about 1% is expected at production, which will be locally reduced when sorting the produced mirrors).

The mirror support has been designed to ensure good rigidity (checked with FEM calculation) and resolution in angular alignment at the 0.2 mrad level.

The finalization of the mirror design has been achieved by an intense prototyping activity concerning mirror substrates, mirror coating, mirror mechanical supports and alignment arrangements.

7. Conclusions

We are building a large-acceptance gas RICH detector to be operational in the year 2000. We have chosen, as far as possible, proven technologies. The choice of MWPCs with CsI photocathodes as photon detectors sensitive in the far UV region has allowed us to instrument a large detection surface at a reasonable cost, but has required great care in the engineering details of the whole project.

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