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COMPASS RICH-1

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Abstract

RICH-1 is a large acceptance gaseous RICH using 3 m of C_4F_{10} as radiator and MWPCs with CsI photo-cathodes as VUV photon detectors. The main characteristics of this RICH are the large acceptance and the use of far UV photon detectors, which implies large dimensions, UV transparencies of the elements up to the photo-cathode, and good UV mirror reflectance.

We give a description of the detector, first results about its performances and a report about various technological achievements required by this challenging project.

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Keywords: COMPASS; RICH; VUV CsI photon detectors; C_4F_{10} gaseous radiator

1. Introduction

The goal of the COMPASS experiment [1] at CERN SPS is twofold: (i) the study of the spin structure of the Nucleon, by measuring ΔG and the transverse structure function h_1, with polarised semi-inclusive DIS reactions and (ii) a rich program of hadron spectroscopy: Primakov reactions, studies of charmed hadrons and

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spectroscopy of light quark systems and glue-balls. The most challenging requirements of this physics programme are high integrated luminosities and hadron identification in crowded environments. Thus, RICH-1 is one of the key detectors of the experiment.

In the following, after a brief description of the RICH parameters, recent upgrades will be presented. A more detailed description of the specific items, i.e. mirrors [2], radiator gas system [3], read-out system [4] and data analysis [5] can be found in other contributions to this conference.

2. RICH-1 design and achieved figures

The requirements for RICH-1, given by 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);
- the minimisation of the amount of material, to preserve the tracking resolution of the small-angle spectrometer and the energy resolution of the downstream electromagnetic and hadronic calorimeters;
- the capability to register and handle high data fluxes.

These requirements resulted in the design sketched in Fig. 1 and in the following achieved parameters:

Radiator: A 3 m long C_4F_{10} radiator at atmospheric pressure [3], with a contamination of oxygen and moisture kept below 5 ppm, to have a transmittance higher than 80% for 165 nm photons, for a typical path length of 4.5 m.

Vessel: For the vessel (~ 80 m^3) non-polluting materials were used, mainly aluminium. Leakage rate is ~ 3 Pa $\times$ l/s.

Mirrors: The mirror system [2] consists of spherical mirrors, radius of curvature 6.6 m, segmented in 116 hexagonal and pentagonal pieces

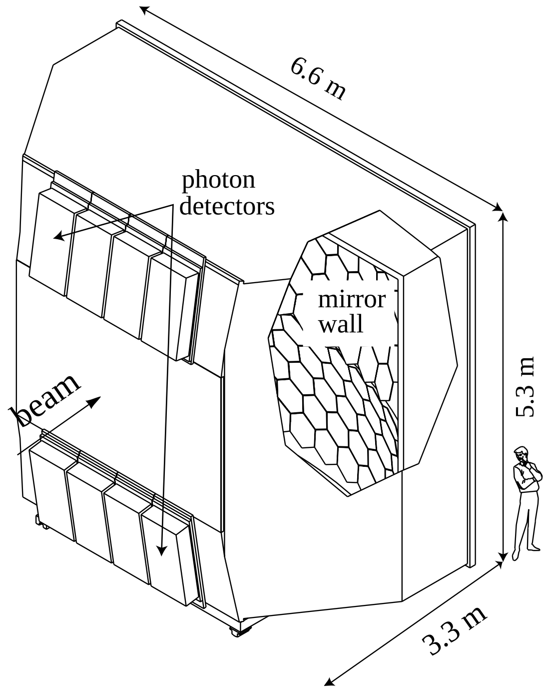

Fig. 1. Artistic view of COMPASS RICH-1.

covering a total area > 20 m^2. Two spherical surfaces focalise the Cherenkov photons onto two sets of photon detectors placed above and below the acceptance region. These mirrors have: local deviation of the shape from the spherical $\sigma_\theta < 0.2$ mrad; maximum deviation from the radius of curvature $\delta_R/R = 0.5\%$, reflectance $> 80\%$ down to 165 nm.

Photon detector: Taking into account the large area to be instrumented (5.3 m^2) and the need for pixel size ~ 1 cm, our choice was to use MWPCs with segmented CsI photo-cathodes, i.e. the UV photon detector developed in the context of RD26 [7] and, later, for the ALICE HMPID project [8], adopted for several other projects (for a general overview see Piuz [9] and for an overview on CSI RICHes see Nappi [9]). RICH-1 is equipped with 8 identical chambers, each one having an active surface of 576×1152 mm^2. Two 576×576 mm^2 double-layer PCBs, each segmented in 5184 8×8 mm^2 pads, coated with CsI form the photo-cathode planes (for more details about the coating technique see Ref. [10]). Fused silica windows ($600 \times 600 \times 5$ mm^3) separate the radiator from the photon detectors. Detail about photon detector design and construction, CsI handling and tests of the small and full-size prototypes can be found in Ref. [11].

Front end electronics: The total of 82 944 channels, equipped with analogic readout electronics, sums at about one half of the total number of channels of the experiment. The heart of the readout system are the large front-end BORA boards [4], housing the front-end chip and local intelligence.

Material budget: The two major contributions to the material budget in the acceptance are the radiator (10.5% of X_0) and the mirrors (5.5% of X_0 for the substrates, 2.5% of X_0 for the mechanical supports); the front and rear vessel windows are sandwiches of two thin Al foils and a layer of rigid foam, resulting in ~2% of radiation length per window. The total radiation length is 22.5% of X_0.

3. The commissioning run in year 2001

3.1. Vessel and radiator

The contamination of the vessel has been monitored during 2001 run, both when it was flushed with N_2, and during the filling and the run with C_4F_{10} (Fig. 2). The two spikes in the oxygen contamination (before filling with C_4F_{10}) are the result of air bubbling inside the vessel through the safety bubbler due to the flux limit in the nitrogen supply line. No similar accident happened running with C_4F_{10} in closed loop, due to the stability of the radiator gas system [3].

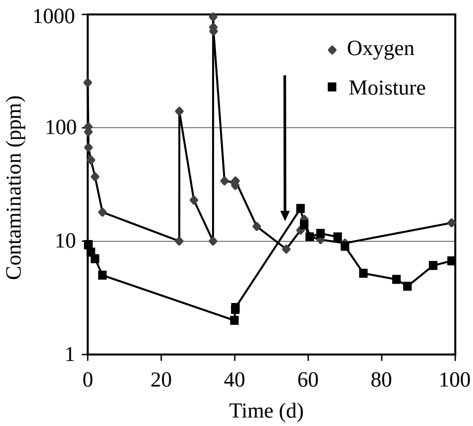

Fig. 2. Vessel contamination, the arrow represent the start-point for the filling with C_4F_{10}.

During the 2001 run only 620 kg of clean C_4F_{10} were available, corresponding to ~60 m^3 of gas. The mixture composition was obtained at the end of the run by measuring the speed of the sound in the gas [6] giving a 55% C_4F_{10} and 45% of nitrogen.

The C_4F_{10} cleaning during 2002 winter allowed to have enough gas to completely fill the vessel for the 2002 run.

3.2. Photon detector

During the 2001 run, six out of eight photon detectors have shown electrical instabilities at the nominal voltage of 2000–2050 V. These instabilities were both rate and voltage dependent. The behaviour was showing a stable chamber for some hours followed by a trip due to an over-current lasting for more than 0.1 s. Studies done using the power supply as a current source, showed that the discharge was self-sustained even at the lower voltage (about 1400 V) given by the current limit, and only the decrease of the voltage below 1000 V was able to stop the phenomenon. After a discharge, it was not possible to raise the chamber at the nominal voltage; only after hours, or even one full day, the chamber was behaving like before. Since two photon detectors were working fine, the problem was not intrinsic of the technology used, but most likely connected with local defects, identified in small tips on the anode wire (they can increase locally the electric field and therefore the gain, resulting in a locally higher flux of ions toward the photo-cathode which can charge the photo-cathode and end in a Malter effect [12] induced discharge [13]; the memory effect is the result of the very large amount of charge generated during the discharge). Local defects of the anode wires have been hunted by reversing the chamber bias voltage. A detected discharge is shown in Fig. 3; the tip is clearly visible, together with the feable light generated.

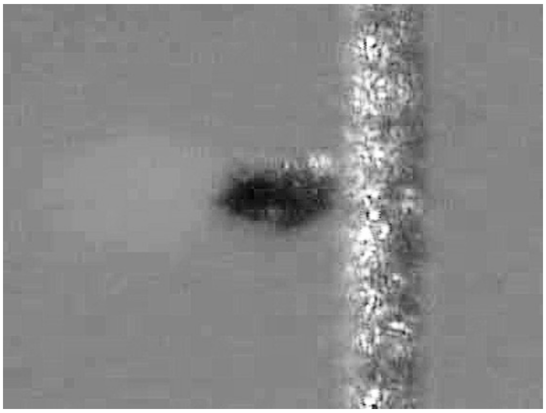

Fig. 3. Tip induced discharge observed at the microscope.

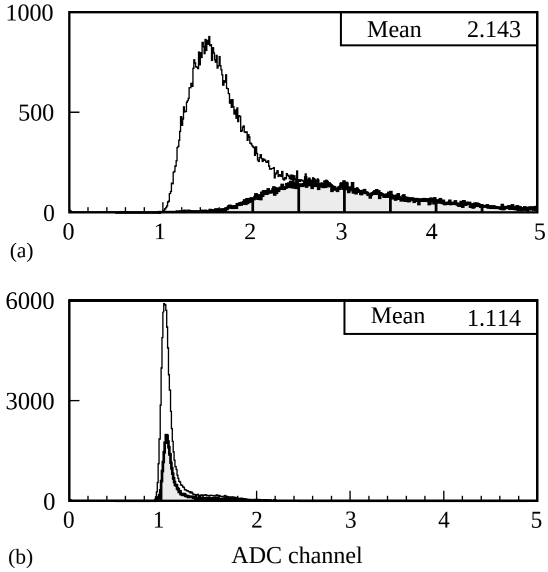

Fig. 4. Noise gain due to improved grounding: (a) Sigma of all the channels for the 2001 run; and (b) same for 2002.

Defects like this were found on about $\frac{1}{3}$ of the LUMA wires,[3] which have been replaced, resulting in a better electrostatic behaviour. The anodes of two photon detectors showing a very bad behaviour under this test have been rewoven completely using 20 μm gold-plated tungsten OSRAM[4] wires.

4. Hints from the 2002 run

The noise calibrations for the 2001 COMPASS run have shown an average noise level (Fig. 4(a)) of 2.14 ADC channel (1 ch ~ 1000 ENC), a factor of two higher than the design value. A more detailed analysis has shown that a large contribution to this was coming from the pads in correspondence to the walls of the grid used to reinforce the photo-cathode PCB (Fig. 4(a), full histogram). To solve this problem 18 new ground connections were introduced between each BORA board and the photo-cathode supporting frame. The noise level after the improved grounding is shown in Fig. 4(b). First hints of the performance of RICH-1 during 2002 run are now available. As a result of the improvements the rings are clearly visible in the online display; Fig. 5 shows a nice multi-ring event, while a blowup of one ring is shown in Fig. 6. The bias voltage of the photon detectors is 2050 V for all the plots presented.

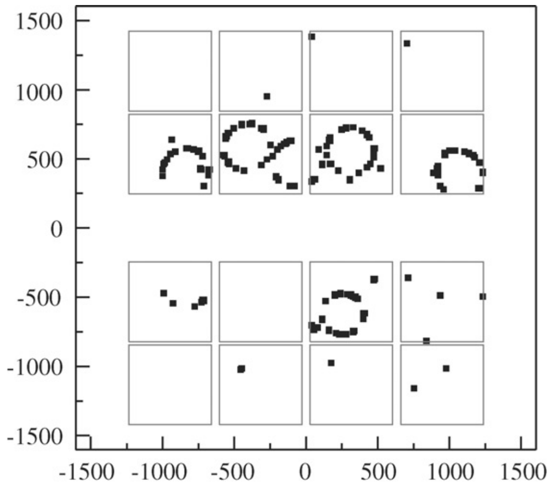

Fig. 5. On line display of one event: the boxes correspond to the frames of the 16 photo-cathodes.

[3] Gold-plated type 860 20 μm tungsten wire, with ~3% of Rhenium(Re). LUMA METAL, Amerikavägen 5, P.O. Box 701, 39127 Kalmar, Sweden.

[4] OSRAM SYLVANIA Lighting research, 71 Cherry Hill Dr, Beverly, MA 01915, USA.

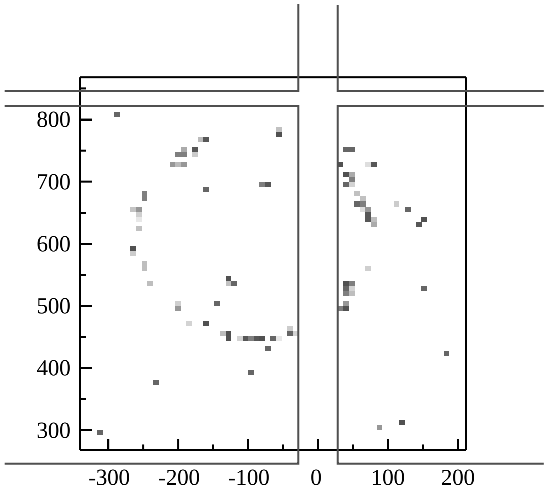

Fig. 6. On line display of one ring shared between two photo-cathodes.

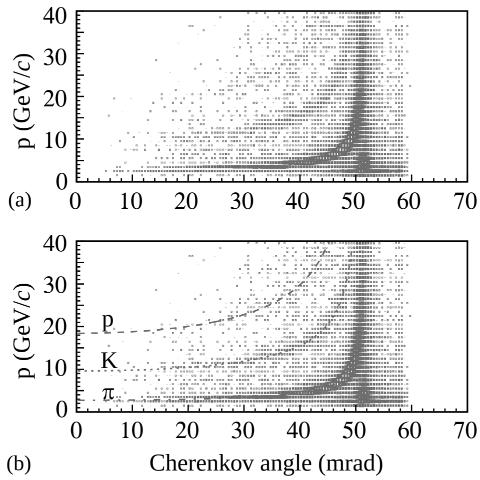

Fig. 7. (a) Distribution of the particle momentum versus the reconstructed ring Cherenkov angle. (b) Same as above with the kinematical curves corresponding to π, K and p loci.

A nice separation between pions, kaons, and protons is also indicated in the preliminary analysis of the low intensity calibration data (Fig. 7).

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