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First performances of COMPASS RICH-1

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Abstract

COMPASS RICH-1, designed in 1996 for hadron identification at high momenta in the COMPASS large angle spectrometer, is based on the use of MWPCs with large size CsI photon detectors. This choice, dictated by technical and economical considerations, has imposed VUV requirements for mirror reflectance and radiator transparency.

The detector is now fully operative and its preliminary performances are presented.

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Keywords: COMPASS; RICH; VUV; CsI photon detectors

1. Introduction

COMPASS RICH-1 [1] has been designed for hadron identification up to ~ 50 GeV/c covering the whole acceptance of the COMPASS [2] large angle spectrometer, namely ± 250 mrad (horizontal) and ± 180 mrad (vertical). Other requirements imposed by the overall spectrometer design are the capability to stand high beam fluxes (up to 2×10^8 per SPS spill lasting 4.8 s) and high trigger rates (up to 10^5 s^{-1}) and the necessity to reduce the detector material to be compatible with the electromagnetic and hadronic calorimeters placed downstream of RICH-1.

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2. Photon detection

Large photon detector surface is needed for COMPASS RICH-1, due to the large detector acceptance, and fast detector response is required to match the COMPASS beam and trigger rates. In mid 1990s, the most natural answer to these requirements was represented by the newly developed gas detectors with large surface CsI photocathodes (see Ref. [3] and references therein). These detectors are multiwire proportional chambers with quite extreme geometrical parameters (for RICH-1 detectors: anode–cathode gap: 2 mm, anode wire diameter: 20 μm, anode pitch: 4 mm). They are operated at moderate gain (typically 5×10^4) as imposed by the presence of a photocathode coated with CsI. The photocathode is a printed circuit board, segmented in pads and coated with a thin layer of CsI (typically: 300 nm). Nowadays, effective quantum efficiency higher than 20% at 170 nm is routinely obtained [4].

For COMPASS RICH-1, 8 MWPCs (active surface: $60 \times 120\ \mathrm{cm}^2$), for a total surface of $5.3\ \mathrm{m}^2$ have been built; presently this is the largest photon detection set-up based on this type of photon detectors. The analog information from the 84,000 channels is read out with a dedicated, original system based on large, custom front-end boards and the use of distributed intelligence [5]. Particular care has been dedicated to the precision of the mechanical components: the thickness of all chamber frames are checked to be the nominal one within 0.1 mm and the planarity of the wire planes are also within 0.1 mm. CsI photocathode handling is demanding as the coated surface must never be exposed to moisture: CsI is highly hygroscopic and the quantum efficiency is degraded after water absorption. RICH-1 photocathode are never exposed to air after coating; they are stored and manipulated in dry, clean atmosphere obtained circulating dry inert gas and the possible air contamination is monitored measuring the oxygen traces (typically at 10 ppm, never above 50 ppm). Various tools have been built to handle the 20 (16 and 4 spare units) $60 \times 60\ \mathrm{cm}^2$ photocathode planes: individual covers allowing gas circulation protect the cathodes during storing and transportation, a dedicated stand alone gas system with closed loop of filtered nitrogen for transportation, dedicated glove-boxes applied onto the MWPCs when photocathodes are mounted or dismounted.

In COMPASS environment, some photon detectors have exhibited electrical instabilities, appearing only at high radiation rates: due to the huge dispersed halo of the muon beam, the photon detectors experience a severe flux of minimum ionising particle almost uniform on the detector surface ($\sim 5 \times 10^5\ \mathrm{m}^{-2}\ \mathrm{s}^{-1}$), while the Cherenkov photon flux is largely non uniform with maximum rate in the region where the image of the halo beam is formed ($\sim 10^5\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$). The instabilities are certainly related to small local defects, in particular of the anode wires: replacing wires with an iterative procedure, part of the detectors have been recovered already for the 2002 run. The refurbishing has been completed before the 2003 data taking period. After a discharge, the photon detectors require long (~ 1 day) recovery time, a behaviour not understood at microscopic level, that requires more investigation.

3. Technological achievements

RICH-1 mirror system [6] consists of a $21\ \mathrm{m}^2$ mirror wall formed by 116 VUV spherical mirrors elements (80% reflectance down to 160 nm at the production and, after a limited initial decrease, stable reflectance above 165 nm over 2 years of operation) and good optical parameters in spite of the thin mirror substrate (7 mm borosilicate glass): radius values 6606 ± 20 mm, spot size (95% of the energy included) 1.65 ± 0.45 mm, surface roughness, r.m.s. 1.26 ± 0.11 nm. The aluminium mechanical support of the mirrors is light (2.5% radiation length equivalent thickness) and stiff (mirrors stable at 0.1 mrad level over 2 years); it allows mirror angular alignment with a resolution of ~ 0.1 mrad.

The radiator gas system [7] allows to keep the vessel pressure stable with respect to the atmospheric one at 0.1 mbar level over months of operation. The gas, cycled in a closed loop, is continuously filtered to remove water vapour and oxygen (residual contaminations at 5 ppm level for both pollutants have been measured); this guarantees the gas transparency (integral light transmission, in the range 165–200 nm, through 2 m long path, larger than 90% has been observed).

4. Preliminary detector performances

Fig. 1 shows an event as appearing on the on-line event display: several rings of different radius are clearly visible.

In the 2002 data, the measured single photon resolution, for high momenta particle, is presently 1–1.1 mrad (the design value is 0.9 mrad), while the resolution for the Cherenkov angle as determined by all the photon forming a ring image is 0.39 mrad to be compared with 0.23 mrad obtained in the simulation. The single photon resolution is mainly limited by the physical background. The ring resolution is limited by the number of detected photons ($\sim$14 per ring, $\sim$25 in the simulation) due to the electrical instabilities of the photon detectors, that forces to operate them at voltages lower than the optimal ones, and to the partial filling of the radiator which has been operated, in 2002, with a gas mixture of C_4F_{10} ($\sim$70%) and nitrogen: complete filling is foreseen for the 2003 run. Nevertheless, the presently achieved resolution corresponds to a 3σ π/K separation up to 40 GeV/c and 2σ separation up to 50 GeV/c. The preliminary mass spectrum as obtained with RICH-1 is presented in Fig. 2.

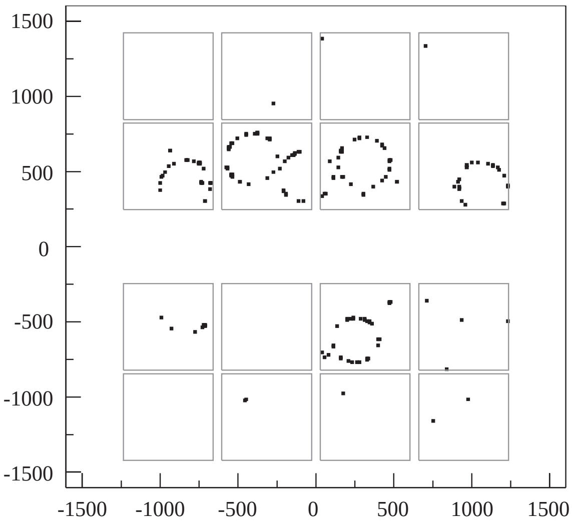

Fig. 1. An event from the on-line event display of COMPASS RICH-1.

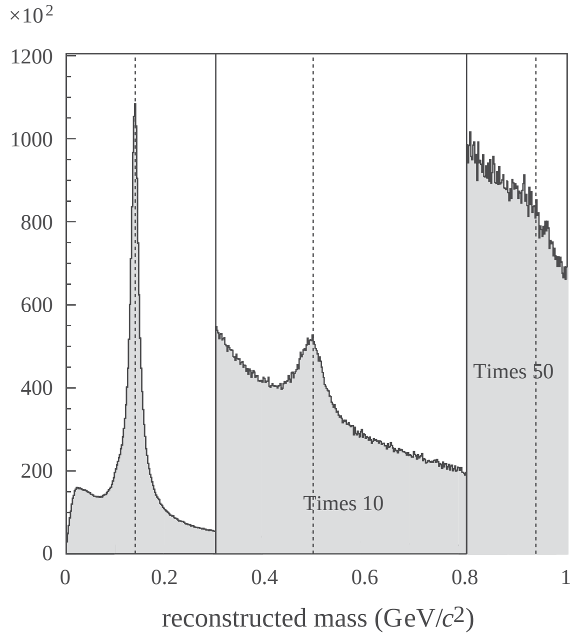

Fig. 2. Preliminary mass spectrum obtained with COMPASS RICH-1; π and K peaks are clearly visible; there is also an indication of p signal.

5. Conclusions

COMPASS RICH-1, a large VUV gas RICH, designed in mid 1990s, with challenging requirements concerning transversal size and rates, is now fully operational.

Limitations in the operation of large size photocathodes coupled to gas detectors in highly radioactive environments have been encountered.

Single photon resolution is already satisfactory; present ring resolution, limited, in 2002 run, by the number of detected photons, allows π/K separation up to $\sim$40 GeV/c. It is expected to increase the number of detected photons with full radiator filling and more stable photon detector behaviour.

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