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The RICH detector of the CBM experiment

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A B S T R A C T

The CBM-RICH detector is designed to identify electrons with momenta up to 8 GeV/*c* and high purity as this is essential for the CBM physics program. The detector consist of a CO_2-gaseous radiator, a spherical mirror system, and Multi-Anode PhotoMultiplier Tubes (MAPMT) of type H12700 from Hamamatsu as photon detectors. The detector concept was verified through R & D studies and a laterally scaled prototype. The results were summarized in a TDR, in which open issues were defined concerning the readout electronics, the shielding of the magnetic stray field in the MAPMT region, the radiation hardness of the MAPMT sensors, and the mechanical holding structure of the mirror system. In this article an overview is given on the CBM RICH development with focus on those open issues.

1. Introduction

The Compressed Baryonic Matter experiment (CBM) is one of the core projects of the future accelerator facility FAIR in Darmstadt, Fig. 1. CBM will investigate the properties of nuclear matter and map the QCD phase diagram in the region of high net-baryon densities available in the laboratory with beam energies of up to 11 AGeV for the heaviest nuclei at SIS100 [1]. CBM has established a worldwide unique physics program [2] covering all known probes of dense nuclear matter. Electromagnetic radiation from dense nuclear matter is of particular importance, therefore CBM allows for either electron or muon identification in two separate setups. Electrons with momenta of up to 8 GeV/*c* will be mainly identified with a Ring Imaging Cherenkov detector (RICH). It is located directly behind a dipole magnet and the tracking system STS and in front of the sub-detectors TRD and ToF, see Fig. 1.

2. The RICH concept

The main challenges for the detector design are the high interaction rates of up to 10 MHz in Au+Au collisions and the high track density with up to 1000 charged particles per event. Thus the detector must be fast and still provide clean electron identification. Combined pion suppression factor with the TRD detector should be between 1000 and 5000. Therefore an efficient single photon measurement and a high number of photons per ring are mandatory.

To cope with these requirements the RICH concept [3,4] aims at a stable, robust and fast gaseous detector relying to a large extent on

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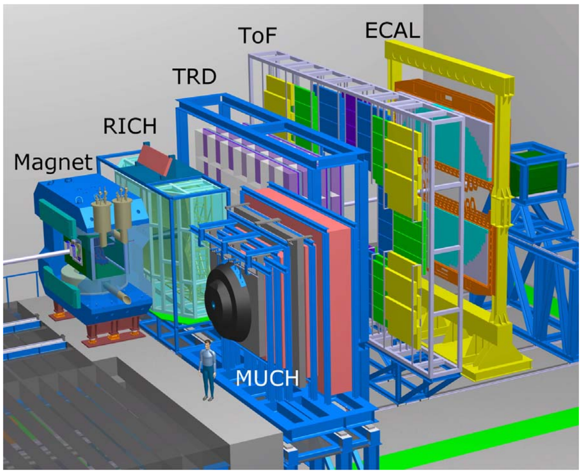

Fig. 1. Design of the CBM experiment. The tracking system STS is located inside the dipole magnet. The RICH detector is located directly after the magnet and before the other sub-detectors: TRD, TOF, and ECAL. The muon identification detector (MUCH) is shown in parking position.

components from industry. Fig. 2 shows the RICH design. The RICH detector is separated symmetrically into two halves above and below the beam pipe with two identical spherical mirror planes and two identical planes of Multi-Anode PhotoMultiplier Tubes (MAPMTs) as photon-detectors. The radiator is a 1.7 m long CO_2-volume at a relative over-pressure of 2 mbar, where the pion threshold for Cherenkov radiation is about 4.65 GeV/c.

Detailed and extensive R & D studies led to the selection of mirrors from JLO-Olomouc and MAPMTs of type H12700 from Hamamatsu. The mirror system is made from SIMAX glass with a Al+MgF_2 reflective and protective coating. It consists of about 80 trapezoidal tiles of approximately 40×40 cm^2 each with a curvature radius 3 m and a thickness of 6 mm. They have very good reflectivity down to wavelengths below 200 nm and a very homogeneous surface, which is essential for ring sharpness. See [5] for more details.

Several PMTs from Hamamatsu (R11265, H8500, H12700) and MicroChannel Plates from Photonis (XP85012) were tested on their crosstalk, single photon response, noise, and quantum efficiency (QE) [6]. R11265 and H12700 show the best results. Due to its larger active area H12700 was chosen as photon detector of the RICH detector. One major milestone achieved in summer 2015 was the ordering of 1100 pieces of this type. Series tests of delivered MAPMTs are ongoing [7]. To enhance the QE Wavelength-Shifting films (WLS) made of p-terphenyl are utilized on top of the MAPMT entrance window. The sensor properties mentioned above were also recorded with WLS layers. Results can be found in [8].

The RICH concept was verified in beam tests at CERN with a laterally scaled prototype. Results [6,9] show good performance in agreement with simulated data: In average about 24 hits per ring could be recorded without WLS coating. The WLS films enhance this number by about 20%. At particle momenta of 8 GeV/c a pion rejection factor of 3500 is reached. All results obtained were summarized in a TDR [5] that was accepted by FAIR in Feb. 2014. In the TDR important open issues were defined regarding the readout electronics, the radiation hardness of the MAPMTs, the shielding of the magnetic stray field in the MAPMT region, and the mirror holding structure.[1] The readout electronics development is covered in [14]. Results from R & D and design activities on the other issues will be presented in this article.

[1] Isotropic emission of fluorescence photons in the WLS layers and its influence on the cross talk and ring sharpness was also raised by the TDR referees. This topic is not covered in the presentation at this conference but is discussed in details in [8].

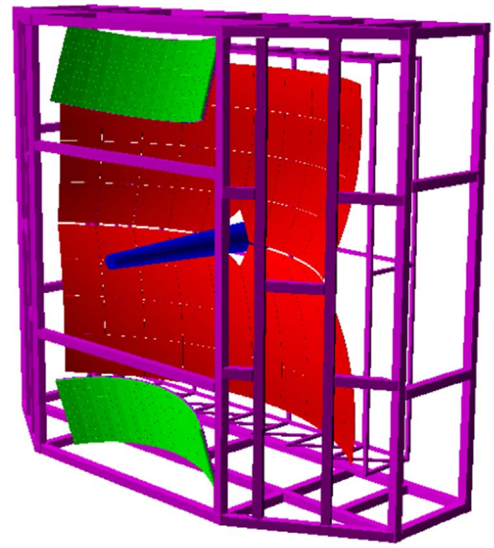

Fig. 2. Design of the CBM-RICH detector. Beside a CO_2-gaseous radiator it consists of a spherical mirror system and MAPMTs as photon detectors. The detector is separated into two halves above and below the beam pipe.

3. Radiation hardness of the MAPMT

Assuming a CBM lifetime of 20 years, simulations with FLUKA show that integrated irradiation doses of up to $10^{12} n_{eq}/\mathrm{cm}^2$ of non-ionizing and up to 100 Gy of ionizing radiation will be accumulated in the inner region of the MAPMT plane (SIS300 conditions: 35 AGeV beam energy and 10 MHz interaction rate). To a large extent the non-ionizing radiation is thermal neutrons, referred to as neutrons in the following. Potentially, both radiation types can lead to QE loss and/or to rising the dark rates in the MAPMTs. The first effect occurs due to coloring of the entrance window, to damage of the photo cathode and/or of the dynodes, or to photoionization of singlet excitation in the WLS coating. The second effect could occur due to activation of the Kovar alloy being part of the metal housing of the MAPMTs.

Different sensors (H12700 and H8500) and sensor components have been irradiated with neutrons in a TRIGA reactor near Ljubljana with high flux of thermal neutrons and/or with high energetic photons (1.2–1.3 MeV) from a ^{60}Co source at the Strahlenzentrum at Giessen University. To determine potential damage, properties of the components were measured before and after irradiation with varying doses.

The coloring of the MAPMT entrance window manifests itself through loss of transmittance. Our measurements show that the transmittance of the MAPMT window (UV glass) was not affected through neutron irradiation doses of up to $10^{12} n_{eq}/\mathrm{cm}^2$. However it is affected through gamma irradiation, albeit only slightly. For a dose of 100 Gy 3% loss of transmittance is observed at 200 nm. At larger wavelengths the loss vanishes. Significant loss is observed only at high integrated irradiation doses of 1 kGy, far beyond the dose expected in the MAPMT region during CBM life time. Within an annual CBM run the window loses less than 0.2% of its transmittance.

WLS coated quartz glasses were irradiated with neutron and gamma rays. The fluorescence intensity was measured before and after irradiation and compared to non-irradiated control samples. No significant effects were observed after neutron or gamma irradiation doses of up to $3 \times 10^{12} n_{eq}/\mathrm{cm}^2$ and 100 Gy respectively.

In order to check the sensor performance, single photon scans were taken channel by channel on different MAPMTs (H8500, H12700) before and after irradiation with neutrons and subsequent with gammas doses of $3 \times 10^{11} n_{eq}/\mathrm{cm}^2$ and 145 Gy respectively. The recorded gain variation due to irradiation is less than 5%.

Gamma spectroscopy of a H8500-PMT was recorded 24 h after irradiation with neutrons. The dose was $1.3 \times 10^{11} n_{eq}/\mathrm{cm}^2$ correspond-