Feasibility Study of Using RPCs in CBM Muon Chamber

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I. INTRODUCTION

The Compressed baryonic matter (CBM) experiment is one of the major scientific pillars at the future accelerator facility for antiproton and ion research(FAIR) in GSI Germany. It is a fixed target experiment aimed to explore the QCD phase diagram in the region of very high net-baryon density by colliding heavy ions in the energy range of 2-45 AGeV at an exceptionally high interaction rate of 10 MHz. The high interaction rate at the CBM experiment would facilitate detection of rare probes like charmonium (J/ψ) and low mass vector mesons (LMVM) with high statistical significance via dileptonic decay channel. The given experimental conditions demand detectors to be radiation hard, together with high rate handling capability. The MUCH (Muon Chamber) detector system in CBM is a segmented absorber system with detectors placed in between them. Until now, the proposed LMVM SIS100 set up for the muon detection consists of 4 hadron absorbers [60C, (20, 20, 30)Fe cm] and 4 detector stations [1]. The first absorber is made of carbon and, the rest are made of iron. Here GEM chambers will be used as active detector elements in the first 2 stations, whereas, STRAW TUBES were the baseline detector technology for the 3^{rd} and 4^{th} stations. Recently it was discussed in the collaboration to replace the STRAW TUBE detectors with Resistive Plate Chambers (RPCs). In this article we report the feasibility of using (bakelite) RPCs as an active detector component in the 3^{rd} and 4^{th} station of CBM-MUCH.

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II. SIMULATION STUDIES OF PARTICLE RATES

As detectors are expected to handle very high rate of particle flux, we have first estimated the number of particles reaching these detectors per unit time. Given the interaction rate of 10 MHz, particle flux per unit time on the 3^{rd} and 4^{th} stations of the MUCH were measured to be 15 kHz/cm^2 and 5.6 kHz/cm^2, respectively, for central Au-Au collisions at 8 AGeV. For minimum bias collisions these rates will be reduced by a factor of 4 approximately.

Since RPCs are known to operate at a rate of $\sim$1 kHz/cm^2, further attempt was made to bring down the particle flux by increasing the absorber thickness. The thickness of the 3^{rd} absorber is increased from 20 cm to 30 cm. Whereas, the 4^{th} absorber thickness was reduced to 20 cm from 30 cm. In this way, the overall radiation length was kept unchanged.

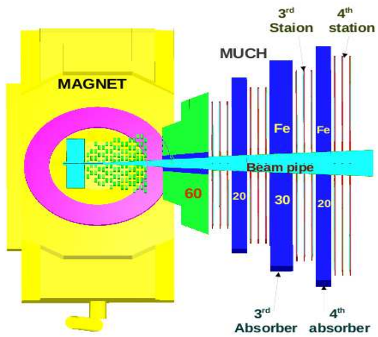

FIG. 1: MUCH setup with 4 stations and 4 absorbers.

The MUCH setup with 4 absorber and 4 station configuration is shown in Fig. 1. The absorber materials are indicated in different colors and their respective thicknesses are also mentioned in the same figure. With this configuration we have calculated the total number of particles impinging on the detector surface using the UrQMD Monte Carlo event generator in the CBMROOT framework. A GEANT3 transport code is used to transport all produced particles through the CBM detector setup.

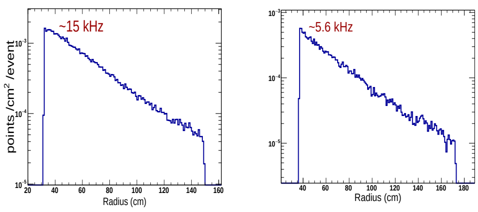

FIG. 2: Point density distribution for the 3^{rd} station (**Left**) and, 4^{th} station (**Right**).

Left and right panel of Fig. 2 shows the density distributions of GEANT3 points of impact that quantifies the number of particles per-unit area per-event. The particle rates on the detector surfaces are obtained by scaling the point density distribution with the 10 MHz interaction rate. The maximum particle rates on the detectors at 3^{rd} and 4^{th} station are found to be 15 kHz/cm^2 and 5.6 kHz/cm^2. However, the estimated particle rates are well above the typical rate handling capability of the single gap high resistive RPCs. So, further optimization is required to improve the rate handling capabilities of the detectors.

III. FEASIBILITY OF RPCS IN CBM MUCH

RPCs are known to handle particle rates ∼1 kHz/cm^2. Several High Energy Physics (HEP) experiments like ALICE [2], CMS [3], ATLAS [4, 5] have used RPCs in their muon trigger system and also proposed the same for future upgradation. The particle-rate handling capability of a RPC[6] depends on several detector parameters as :-

$$\text{Rate capability} = \frac{1}{\rho t < Q >} \quad (1)$$

where, ρ is the bulk resistivity of the electrode material; t is the total thickness of both the electrodes and $< Q >$ is the average charge created in the gas gap for each count. As seen from Eq. 1, the rate handling capability can be increased by suitable optimization of each of the three parameters. For, $\rho = 10^8$ Ωcm, t = 0.3 cm and $< Q > \approx$ 1pC, the RPC can easily handle a particle rate of ∼16 kHz/cm^2. The following table summarizes the rate capability of RPCs used in HEP experiments.

TABLE I: This table shows the particle rate handling capability of RPCs in various HEP experiments along with the bulk resistivity (ρ) of the electrode material of the RPCs

Experiment	Rate (kHz/cm^2)	$\rho_{electrodes}(\Omega cm)$
ALICE	∼10	$10^9 - 10^{10}$
CMS	∼10	10^{10}
ATLAS	∼14	10^{10}

IV. CONCLUSION AND OUTLOOK

RPCs have been successfully operated in several HEP experiments with ∼1kHz/cm^2 particle rates. A proper optimization of the bulk resistivity and thickness of the electrodes can help us to develop RPCs to be used in CBM MuCh. As the gas mixture flown in RPC also determines the charge accumulated in each count, *R&D* on the gas mixture can also be done to increase the rate handing capability of the RPC. Work has started at VECC for building prototype RPCs for CBM experiment.

References

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