Feasibility study of using RPC in the muon detection system of the CBM experiment at FAIR.

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Introduction

The Compressed Baryonic Matter (CBM) experiment at FAIR is a next-generation fixed target experiment that will explore the QCD phase diagram in the region of exceptionally high net baryon density (~5-10 $\rho_{Nuclear}$) by colliding heavy nuclei in the energy range 6-40 AGeV [1]. The main objective of CBM experimental program is to study the properties of nuclear matter produced in an environment of high net baryon density by using variety of probes that include production of strange and multi-strange particles, dilepton production, charm production and production of exotic hypernuclei, etc. Among them, dilepton measurement has received considerable interest, as it is associated to the search for the onset of chiral symmetry restoration. One of the unique features of the CBM experiment is, that it will be operated at an interaction rate of ~10MHz. Thus, high rate handling capacity is a primary requirement for the detector systems at CBM. The CBM muon detection system also known as the Muon Chamber (MUCH) or CBM-MUCH will be specifically designed & built for detection of muon pairs at this high interaction rate. The CBM-MUCH has a uniquely designed segmented absorber system with detector layers (stations) placed in between them. While the Gas Electron Multiplier (GEM) will be used as active detector element in first two stations, for the 3rd and the 4th station use of Resistive plate chambers (RPCs) is currently foreseen. In the standard MUCH setup of 4 stations + 4 absorber, the absorber thicknesses are 60+20+20+30 cm, down the beam-line. As RPC might not be able to handle very high interaction rate, it was planned to modify thickness of 3rd and 4th absorber to 30 cm and 20 cm, respectively so as to reduce the particle rate. In this article, we report the performance of CBM-MUCH with implementation of this modified geometry.

Geometry Implementation and Simulation Study

Fig 1. shows the modified geometry of MUCH with 3 stations + 3 absorbers known as SIS100A geometry and 4 stations + 4 absorbers, known as SIS100B. We have implemented modified thicknesses of 3rd and 4th absorber in these two geometries. 3rd absorber thickness has been increased to bring down the particle rate within RPC's rate handling capability.

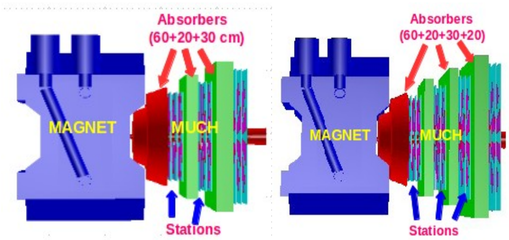

Fig. 1 Geometry for modified SIS100A (3 stations + 3 absorbers) setup left and modified SIS100B (4 stations + 4 absorbers) setup right figure.

From GEANT3 simulation we get a hit (called point) rate ~ 15KHz/cm^2 in the 3rd station and ~5.6 KHz/cm^2 in the 4th station which are within the rate capability of RPC [2] which is shown in Fig.
2.

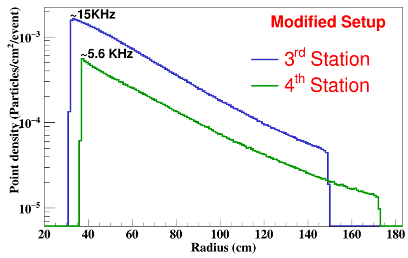

Fig. 2 Point density (particles/cm^2/event) distribution for 3rd and 4th station for modified absorber thickness.

The simulation for point density calculation has been performed at 8 AGeV minimum bias Au+Au interactions. We proceed further to study the performance of this modified geometry w.r.t invariant mass distribution, pair reconstruction efficiency of the detector and signal to background ratio (S/B) of ω vector meson via dimuon decay channel for both SIS100A and SIS100B .

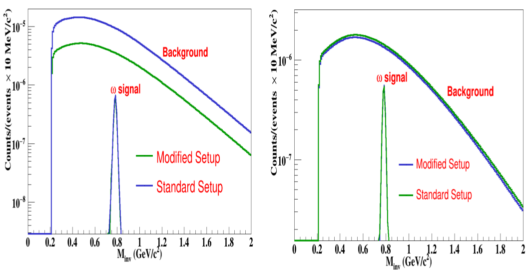

Fig. 3 Invariant mass distribution of ω and combinatorial background through dimuon combination for SIS100A (left) & SIS100B (right) geometries.

To generate signal ω we have used PLUTO [3] event generator and background particles are generated from UrQMD [4]. Embedded events have been transported through GEANT3 and dimuons have been reconstructed and selected through some selection cuts mentioned below. For SIS100A setup, selection cuts for choosing dimuons are following - STS hits ≥ 7, MUCH hits ≥ 8 , $\chi^2_{vertex} \leq 2.1$, $\chi^2_{MUCH} \leq 1.3$. For SIS100B , selection cuts are STS hits ≥ 7, MUCH hits ≥ 11 , $\chi^2_{vertex} \leq 2.0$, $\chi^2_{MUCH} \leq 1.3$. After selecting muon pairs, super event technique was used to obtain background invariant mass distribution.

Results and Discussions

The pair reconstruction efficiency and S/B for ω have been compared w.r.t standard MUCH set up. Fig 3. shows the invariant mass distribution of signal ω and combinatorial background for SIS100A (left) & SIS100B (right). For SIS100A, S/B improves for the modified geometry at the cost of efficiency. This is expected as the total absorber thickness for the modified setup (60+20+30 cm) has increased by 10 cm as compared to the standard SIS100A (60+20+20 cm). This is also reflected in efficiency and S/B values for SIS100A, quoted in table.1. Whereas, for SIS100B, the total absorber thickness for modified setup (60+20+30+20 cm) and standard setup (60 +20+20+30 cm) remains same, except interchanging the positions of 3rd and 4th absorber. Therefore, the total radiation length of absorber material remains same for SIS100B.

Table 1: Comparison of ω efficiency and S/B for SIS100A & SIS100B modified setup with standard one.

Setup	**SIS100A standard**	**SIS100A modified**	**SIS100B standard**	**SIS100B modified**
ω eff (%)	1.21	0.9	1.02	1.01
S/B	0.04	0.07	0.18	0.19

Thus, it is expected to have similar invariant mass distribution of signal ω and background as shown in Fig 3. The same conclusion can be drawn from the efficiency and S/B values in Table 1, that do not exhibit any significant change for SIS100B. Our study therefore reveals, changing 3rd & 4th absorber thicknesses can affect the performance of ω in SIS100A but for SIS100B the effect is negligible.

References

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