Di-muon measurements for the development of the muon chamber and particle production in the CBM experiment at FAIR

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Introduction

The Facility for Antiproton and Ion Research (FAIR) is an accelerator complex under construction near the Gesellschaft Schwerionen (GSI) research centre in Darmstadt, Germany. Its backbone are two superconducting synchrotons (Schwerionen Synchrotron (SIS)-100 and SIS-300) with 100 and 300 Tm bending power respectively, delivering high intense beams of protons (upto 90 GeV), light ions (upto 45 GeV per nucleon) and heavy ions (up to 35 GeV per nucleon). The Compressed Baryonic Matter (CBM) experiment is being constructed to be operated at this facility from 2018. It will investigate nuclear matter under extreme conditions (temperature, density) as produced in relativistic nuclear collisions. The collision energies available with the SIS-100 and SIS-300 accelerators will provide access to the high-density regime of the phase diagram of strongly interacting matter. CBM will search for the landmarks of this phase diagram as predicted by theory, namely the onset of the transition from confined to deconfined matter, the critical point and onset of chiral symmetry restoration. The CBM physics programme is complementary to the heavy-ion research conducted at Relativistic Heavy Ion Collider (RHIC), USA and Large Hadron Collider (LHC), Switzerland. The emphasis of CBM will be the measurement of rare probes giving access to the early stage of the collisions, like charmed hadrons (J/ψ), multi-strange hyperons and leptonic decays of low mass vector mesons (ρ, ω, ϕ). As the expected multiplicities of these observables are extremely low, their measurement requires high interaction rates, which drive the experimental requirements. Consequently, CBM is being designed to cope with the collision rates of up to 10 MHz, unprecedented in heavy-ion experiments so far. Such rates call for a fast and radiation hard detectors and read-out electronics, but also constitute challenges for the data acquisition, online data reduction and processing. The experiment will operate in fixed-target mode and measure charged hadrons, electrons and muons as well as photons.

The plan of thesis is structured as follows :

Chapter 2 starts with the general introduction to the CBM experiment at FAIR. The measurements of bulk hadrons, multistrange hyperons, hypernuclei, charmonium and low mass vector mesons in nuclear collisions require a large acceptance, high rate detector system. The proposed detectors of this experiment are Silicon tracking System (STS), Micro Vertex Detector (MVD), Time of Flight (TOF) detector, Ring Imaging Cherenkov (RICH) detector, Transition Radiation Detector (TRD) , Muon Chamber (MUCH), Electromagnetic Calorimeter (ECAL) and Projectile Spectator Detector (PSD).

Chapter 3 starts with the introduction to the Muon Chamber (MUCH). One of the important aspects of the CBM experiment is to look for rare probes like charmonia (J/ψ,ψ' etc.) having extremely low production cross section in the FAIR energy regime. Char-

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monia as well as low mass vector mesons (ρ, ω, ϕ) can be measured via their decay in di-muons. Thus a Muon Chamber is needed to detect these dimuons. The MUCH system consists of six alternating layers of absorbers and triplets of tracking chambers [1]. The first few tracking chambers will be of Gas Electron Multiplier (GEM) detectors. The feasibility studies are done within the CBM simulation framework which allows full event simulation and reconstruction. The ingredients used for the simulation are : a) PLUTO generator for phase space decay of the vector mesons taking multiplicities from HSD. b) UrQMD generator for background particles. c) GEANT3 for transport of the generated particles through the setup. d) Kalman Fitter (KF) for tracking. The detection procedure involves the reconstruction of the track parameters in STS and extrapolation to muon detecting stations through the absorbers. Selection of the number of muon stations decides the identification of muons from low mass vector mesons (LMVM) and charmonia. While the LMVM muons travel shorter distances, J/ψ muons cross the thick absorber and reach till the end. We have therefore taken tracks travelling through 15 layers and 18 layers as valid muon candidates from LMVM and charmonia respectively. Our studies indicate that both low mass vector mesons and charmonia can be identified above the combinatorial background which is dominated by muons from weak pion decays.

Chapter 4 starts with the introduction to Gas Electron Multiplier (GEM) detector. A large acceptance, high-granularity and high rate muon detection system (MUCH) is proposed to be built in the CBM experiment for carrying out the measurements of charmonium(J/Ψ) and low mass vector mesons by their muonic decay channels in high energy heavy ion collisions. For the first few stations, where the particle rates reach 1 MHz/cm^2, GEM-based detectors are being developed as tracking chambers. This chapter illustrates the research and development on GEM and addresses the analysis of measurements of cosmic muons as well as X-rays from a Fe^{55} source [2]. The first prototype has been built with the intention of learning about development and commissioning of such a detector from the very beginning. The following section illuminates the testing of triple GEM at CERN-SPS using self triggered electronics in terms of efficiency, cell multiplicity, timing and pulse height spectra.

Chapter 5 deals with the study of particle production mechanism at CBM energies using different models such as statistical thermal model and transport models [3].The main motivation of this study is to show what one should expect in context to particle multiplicities and particle ratios at CBM energy range i.e. 10 A GeV to 40 A GeV lab energies (4.43 GeV to 8.71 GeV center-of-mass energies) , in view of equilibrated statistical as well as transport models. We have also compared the model results with available experimental data of Alternating Gradient Synchrotron (AGS) and Super Proton Synchrotron (SPS) energies.

In **Chapter 6**, we present a summary and conclusion drawn from this work and provide some insights in this area for future research work.

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