J/ψ reconstruction via dimuon dacay channel for CBM experiment at FAIR

A. K. Sharma[1],* P. P. Bhaduri [2,3], T. Galatyuk[4], A. Senger[4], N. Ahmad[1], and S. Chattopadhyay[4]

[1] *Department of Physics, Aligarh Muslim University, Aligarh-202001, INDIA*
[2] *Variable Energy Cyclotron Center, Bidhan Nagar, Kolkata-700064, INDIA*
[3] *Homi Bhabha National Institute, Anushakti Nagar, Mumbai-400094, INDIA and*
[4] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, GERMANY*

Introduction

The Compressed Baryonic Matter (CBM) experiment [1], currently under construction at the FAIR accelerator facility in Darmstadt, Germany, is designed to explore the QCD phase diagram in regions of high net baryon densities and moderate temperatures. The SIS-100 accelerator ring of FAIR will provide beams with energies up to 30 GeV for protons, 15A GeV for light ions (such as C, Ca, Ni ...), and 12A GeV for heavy ions (including Pb, Au, In,..). CBM physics program includes the pioneering measurement of sub-threshold charm production by detecting J/ψ mesons below their kinematic production threshold. This article will present the reconstruction of J/ψ mesons via their di-muon decay channel ($\mu^+\mu^-$) in Au-Au collisions at 10 AGeV for the CBM experiment at FAIR.

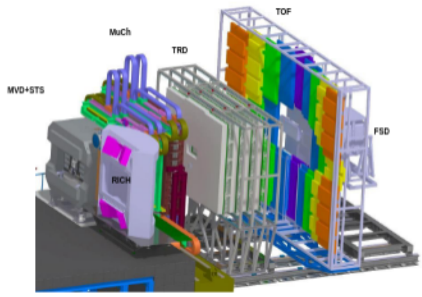

FIG. 1: Schematic of CBM experimental setup.

The experimental setup of the CBM experiment includes several detectors. The Silicon Tracking System (STS) is responsible for reconstructing tracks and determining the momentum of charged particles. For dilepton measurements (e^+e^- and $\mu^+\mu^-$), the Muon Chamber (MuCh) is used for muon identification, while the Ring Imaging Cherenkov (RICH) detector is employed for electron identification. These two detectors are used alternately depending on the measurement channel. Following them, the Transition Radiation Detector (TRD) is utilized for identifying secondary electrons, and the Time of Flight (TOF) detector aids in hadron identification. At the end of the detector setup, the Forward Spectator Detector (FSD) is positioned to determine the centrality of collisions by measuring the energy deposited by the spectator neutrons.

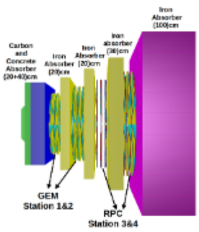

FIG. 2: Muon Chamber Detector layout

For the detection of J/ψ mesons in the dimuon decay channel, the MuCh detector setup [2] includes four stations all made of gas deectors, and five hadron absorbers,Gas Electron Multipliers (GEM) technology is employed in the first two stations, while Resistive Plate Chambers (RPCs) are used in the third and fourth stations. The first absorber is com-

*Electronic address: abhishekhep@gmail.com

posed of 30 cm concrete and 28 cm high density graphite with a combined thickness of 58 cm. The remaining absorbers are made of iron to halt hadrons produced during collisions. The second and third absorbers are each 20 cm thick, the fourth is 30 cm, and the final absorber consists of a 1-meter-thick slab of iron, ensuring that only high-energy muons reach the end of the detector. Additionally, the TRD functions as the fifth station to register trigger hits in the J/ψ detection process.

For the present simulation, 1 million central (0-10%) Au-Au collision events at 10 AGeV are generated using the UrQMD particle generator[3] to produce the background, while the Pluto event generator is employed to generate the J/ψ signal. These generated particles are then processed through the CBM experimental setup using the GEANT3 transport engine. As particles interact with the active medium of the detectors, they generate Monte Carlo (MC) points, representing the locations of energy deposition, and MC tracks. From these MC points, the detector response, known as "digis," are created for each detector based on its specific technology. Clustering algorithms are then applied to combine the neighbouring digis to form hits on the detectors, which are subsequently used to reconstruct particle tracks.

The muons coming from J/ψ decay must pass through the entire CBM experimental detector setup, which includes the STS, MuCh, TRD, and TOF detectors. Several track selection cuts are employed for background rejection and to select muons from J/ψ decays. These include the number of hits associated with a reconstructed track, recorded in the STS, MuCh, TRD, and TOF detectors. Additionally, the χ^2 value from track fitting in the vertex, STS, and MuCh detectors are used as essential criteria for background rejection and selection of suitable muon track candidates. To further reduce the presence of punch-through hadrons, a 2σ TOF mass cut is applied.

The di-muon invariant mass spectrum is obtained by combining the oppositely charged muon candidate tracks on event by event ba-

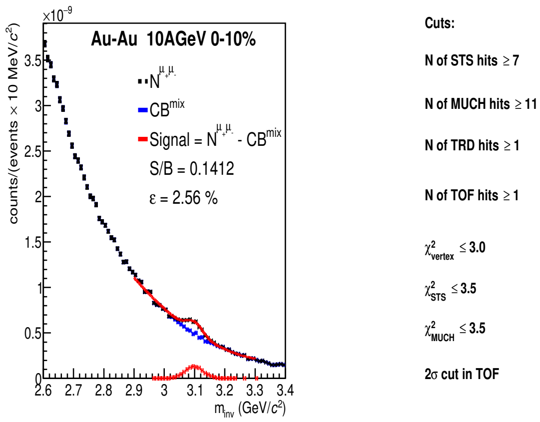

FIG. 3: Invaraint mass spectra of J/ψ meson along with combinatorial background in the dimuon decay channel

sis, is displayed in Fig. 3. The combinatorial background is calculated using super event (SE) analysis. The signal distribution after subtracting the combinatorial background is then normalized by the predicted subthreshold J/ψ multiplicity (5 x 10^{-6}) and the branching ratio of (0.06) for J/ψ decay into dimuons. The signal is fitted with a symmetric Gaussian function with mean($\mu = 3.097$) mass of J/ψ and sigma($\sigma = 0.04$), while the background is fitted with a second-degree polynomial (poly2). The signal-to-background(S/B) ratio is found to be 0.1412, with a reconstruction efficiency(ϵ) of 2.56%. Work is under progress to apply machine learning algorithms based on multivariate analysis for improvement in the reconstruction performance.

References

[1] The CBM physics book: Compressed baryonic matter in laboratory experiments, DOI :10.1007/978-3-642-13293-3

[2] Probing Dense QCD Matter: Muon Measurements with the CBM Experiment at FAIR, Senger, Anna and Senger, Peter DOI:10.3390/particles4020019.

[3] Sub-threshold charm production in nuclear collisions, Steinheimer, J. and Botvina, A. and Bleicher, M. DOI:10.1103/physrevc.95.014911.