J/ψ detection via di-muon channel in 30 GeV p+Au collisions at FAIR SIS100

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The CBM experiment at FAIR-SIS100 aims to study charm production in relativistic nuclear collisions. These charm quarks and antiquarks can interact with the medium to form various states, including D mesons, charmed baryons (like Λ_c), and charmonium states such as J/ψ and $\psi\prime$. In the low-energy fixed target collisions anticipated from SIS100, the formation time of J/ψ mesons is notably short relative to the reaction volume. This feature makes the kinematic coverage of the CBM experiment particularly advantageous for investigating the yet unmeasured interactions between fully formed J/ψ mesons and the dense nuclear medium. By systematically measuring J/ψ production in proton-nucleus (p + A) collisions with different mass numbers (A) of the target nucleus at proton beam energies up to 30 GeV, researchers can gain valuable insights into the inelastic interactions and dissociation of J/ψ mesons in a cold nuclear matter ($\rho = \rho_0 \simeq 0.16/fm^3$) environment. To assess the feasibility of such measurements, we have been conducting physics simulations focused on J/$\psi \rightarrow \mu^+\mu^-$ reconstruction in 30 GeV p + Au collisions using the CBM Muon Chamber (MuCh) setup [1].

In earlier studies, the phase space distributions of J/ψ mesons, including transverse momentum (p_T) and rapidity (Y), were generated using the PLUTO event generator. PLUTO generates J/ψ mesons with transverse mass $m_T = \sqrt{m^2 + p_T^2}$ and Gaussian rapidity distributions at the kinetic freeze-out with freeze out temperature (T_{kin}) and width of the Gaussian (σ_y) as the input parameters [2]. However, the applicability of such thermal distributions for J/ψ production in low-energy p+A collisions is questionable. So, in this study, we utilize the PYTHIA [3] event generator to simulate non-thermal phase space distributions of J/ψ mesons at FAIR energy domain. PYTHIA produces J/ψ mesons through string fragmentation, following the

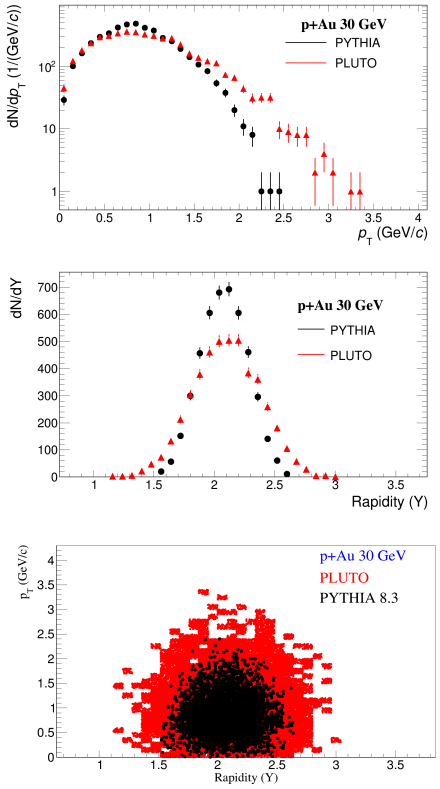

FIG. 1: p_T, rapidity (Y) and Y-p_T distribution of J/ψ at 30 GeV p+Au collisions obtained from PLUTO (red) and PYTHIA 8.3 (black), before applying detector effects.

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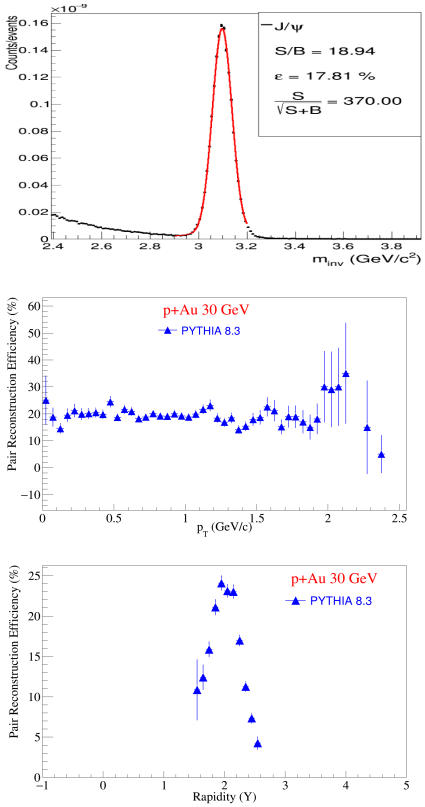

FIG. 2: Invariant mass distribution of J/ψ at 30 GeV p+Au collisions obtained from PYTHIA 8.3 after applying detector effects (top). Pair reconstruction efficiency of J/ψ has been plotted w.r.t p_T (middle) and rapidity (Y) (bottom).

LUND string fragmentation model.

We have used the PLUTO and PYTHIA-8.3 generators to compare thermal and non-thermal J/ψ production in p+A collisions at FAIR with a 30 GeV proton beam. For PYTHIA, we simulate pp collisions, as at such low energy, pp and p+A interactions are quite similar. After generating J/ψs, they are decayed to muon pair using TGenPhaseSpace. Figure 1 illustrates the transverse momentum (p_T), rapidity (Y) and Y-p_T distributions of J/ψ mesons at 30 GeV, generated by PYTHIA (black line) and PLUTO (red line) at the generator level. It appears from Fig.1 that PLUTO produces broader transverse momentum and rapidity distributions compared to PYTHIA.

Our goal is to evaluate the final reconstruction of J/ψ via the di-muon channel after passing through the CBM muon detector set up. To achieve this, we simulated 1 million J/ψ events using PYTHIA and compared the results with PLUTO. Background particles were generated by simulating p+Au collisions at 30 GeV using UrQMD generator. The J/ψ signal (J/$\psi \rightarrow \mu^+\mu^-$) from PYTHIA was then embedded with the UrQMD background and transported through the detectors. After final reconstruction, J/ψ candidates were extracted using the following optimized di-muon selection cuts: A reconstructed track should have associated MuCh hits ≥ 6, STS hits ≥ 5, TOF hits ≥ 1, $\chi^2_{MUCH} \leq 4$, $\chi^2_{STS} \leq 2.5$, and $\chi^2_{VERTEX} \leq 2.5$. Figure 2 shows the reconstructed invariant mass distribution of J/ψ and its efficiency in different p_T and Y bins. From PYTHIA, the J/ψ reconstruction efficiency and S/B are 17.8% and 18.9, respectively, while PLUTO yields an efficiency of 14.5% and S/B of 17. Efficiency with respect to p_T appears flat, whereas efficiency in rapidity (Y) is highest around the mid rapidity in laboratory frame and decreases at lower and higher rapidities due to detector acceptance effects. The results show that with the muon chamber set up of CBM, J/ψ detection is feasible independent of the input phase space distribution of the decay muons.

References

[1] https://repository.gsi.de/record/161297/files/much-tdr-final-for-gsi-report.pdf

[2] I. Fröhlich et al., Pluto: A Monte Carlo Simulation Tool for Hadronic Physics, PoS ACAT 076, (2007).

[3] Torbjörn Sjöstrand et al., An Introduction to PYTHIA 8.2, arXiv 1410.3012 [hep-ph].