$J/\Psi \rightarrow ee$ and $J/\Psi \rightarrow \mu\mu$ Measurements in $AuAu$ and pp Collisions at $\sqrt{s_{NN}} = 200\ GeV$

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First results are presented from $J/\Psi \rightarrow ee$ and $J/\Psi \rightarrow \mu\mu$ measurements by the PHENIX experiment at RHIC. These results are from a preliminary analysis of dielectrons from $AuAu$ and pp data and dimuons from pp data measured in the RHIC run 2. A total cross section for J/Ψ production in $\sqrt{s} = 200\ GeV$ pp collisions of 3.8 ± 0.6 (stat) ± 1.3 (sys) μb is found. The $J/\Psi \rightarrow ee$ yield is presented versus number of binary collisions.

1. Introduction

Interesting results obtained at the CERN SPS [1] have heightened theoretical interest in J/Ψ production in relativistic heavy ion collisions. A new generation of models has appeared in which both dissociation and recombination of $c\bar{c}$ pairs play a significant role. There are now model predictions for RHIC central collisions ranging from the almost complete disappearance of J/Ψ [2], to J/Ψ enhancement [3].

In this paper we present the first results from PHENIX on J/Ψ production at RHIC.

2. Measurements and Analysis

PHENIX [4] detects electrons in the pseudo-rapidity range $\eta = \pm 0.35$, and muons in the range $1.2 < \eta < 2.2$. In the central arms, electrons are identified by matching charged particle tracks to energy deposits in the Electromagnetic Calorimeter and rings in the Ring Imaging Cherenkov Detector. In the muon arms, muon candidates are found by identifying roads in the Muon Identifier, and matching them to tracks found in the Muon Tracker.

During the 2001/2002 RHIC run, PHENIX recorded data from both $AuAu$ and pp collisions. Only the south muon arm was operational during that run.

2.1. pp

Data from pp collisions were recorded for an integrated luminosity of 150 nb^{-1}. The minimum bias interaction trigger for the present analysis was the Beam-Beam Counter (BBC), with at least one hit per arm.

Interaction rates for pp varied from about 5 KHz to 30 KHz. J/Ψ events were selected using level-1 triggers [5] in coincidence with the minimum bias interaction trigger. The

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$J/\Psi \to ee$ trigger used in this analysis (about half of our pp data sample) required that at least 700 MeV be deposited in the Electromagnetic Calorimeter. The $J/\Psi \to \mu\mu$ trigger required at least one deep muon and one shallow muon in the Muon Identifier. The level-1 triggers allowed all J/Ψ events to be recorded at the highest interaction rates. After vertex cuts ($\pm$ 35 cm for ee and $\pm$ 38 cm for $\mu\mu$) and selection of good runs, about 1×10^9 events were sampled for ee and 1.7×10^9 events were sampled for $\mu\mu$. The muon arm data were subdivided into two rapidity bins.

Detector acceptance, level-1 trigger efficiency, and detector efficiency were estimated for a typical run using simulations of single J/Ψ decays with a realistic detector response. An average correction for run-to-run variations in detector active area was then determined from the azimuthal distribution of electrons/event for all runs used in the analysis.

For the ee case, two models of the transverse momentum distribution and a range of values for the mean p_T were used to establish the systematic uncertainty in the acceptance. This was necessary because the p_T distribution is not well defined by the data due to low statistics. This systematic uncertainty was estimated to be 10%.

For both the ee and $\mu\mu$ cases, PYTHIA simulations were used to estimate the BBC trigger efficiency for inelastic pp events (needed to calculate the total number of events), and to estimate the fraction of events containing a J/Ψ that fired the BBC trigger (ie. the BBC trigger efficiency for J/Ψ detection).

For cross section calculations, the RHIC luminosity was assumed to have a systematic uncertainty of 20% in this preliminary analysis. This uncertainty is expected to be reduced considerably with more study.

Systematic errors were added in quadrature to produce an overall systematic uncertainty of 35% for $pp \to J/\Psi \to ee$ and 29% for $pp \to J/\Psi \to \mu\mu$ cross section data.

2.2. AuAu

Data from $AuAu$ collisions were recorded for an integrated luminosity of 24 μb^{-1}. The minimum bias trigger used for $AuAu$ collisions was a coincidence between the BBC (2 hits per arm) and the Zero Degree Calorimeter (ZDC). At the highest luminosities, where only a fraction of the interactions could be recorded, level-2 triggers [5] were used to select J/Ψ events and minimum bias triggers were allocated only $\sim$ 20% of the data bandwidth. Interaction rates varied from about 100 Hz to 1600 Hz. At the end of the $AuAu$ run, the data samples from minimum bias triggers and level-2 triggers were approximately equal.

In the present preliminary analysis of the $AuAu$ data, only the $J/\Psi \to ee$ data have been analyzed, and only minimum bias triggers were used. After applying a vertex cut of $\pm$30 cm and selecting good runs, $\sim$ 26 million events were analyzed.

Yields were extracted using 7 different procedures for yield and background estimation, to establish the systematic errors. The acceptance and detector efficiency were estimated using simulations of single J/Ψ decays with a realistic detector response. The minimum bias trigger is estimated [6] to have unit efficiency for the most central 90% of interactions used in this analysis.

The event centrality was estimated [6] using the combined data from the BBC and ZDC detectors. The data were separated into three centrality bins. The centrality dependence of the efficiency for offline J/Ψ reconstruction was estimated by embedding simulated single electrons into measured events and then taking the square of the single electron

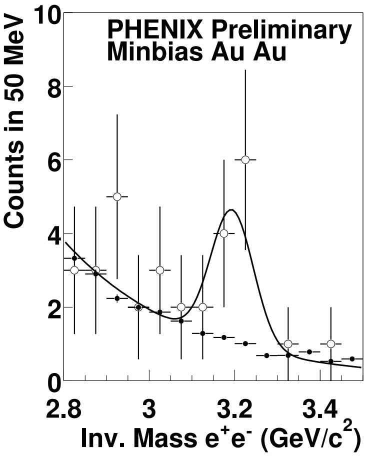

Figure 1. Minbias $AuAu \to ee$ invariant mass spectrum, with mixed background and gaussian plus exponential fit to the J/Ψ peak.

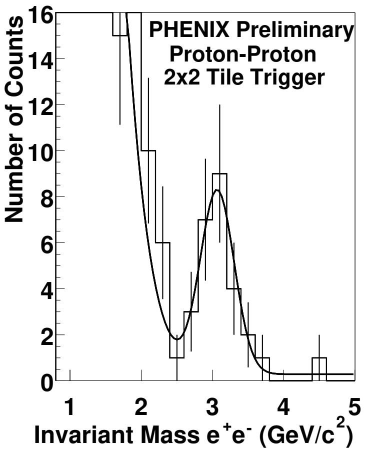

Figure 2. Minbias $pp \to ee$ invariant mass spectrum, with gaussian fit to the J/Ψ peak.

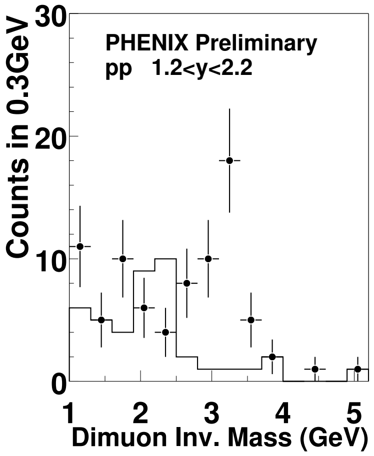

Figure 3. Minbias $pp \to \mu\mu$ invariant mass spectrum (points), with unlike-sign pair background (histogram).

reconstruction efficiency as the J/Ψ reconstruction efficiency due to occupancy.

Combining systematic errors quadratically produced an overall systematic uncertainty per centrality bin of 26% (0-20%) 27%(20-40%) and 26%(40-90%).

3. Results

The dielectron invariant mass spectrum from $AuAu$ (minimum bias) is shown in Fig. 1, and that from pp is shown in Fig. 2. Fig. 3 shows the pp dimuon invariant mass spectrum.

The J/Ψ rapidity distribution was obtained by combining the data from the ee and $\mu\mu$ channels, and is shown in Fig. 4. The total cross section was obtained by fitting both a Gaussian and the PYTHIA prediction for the shape of the rapidity distribution, using the parton distribution function GRV94LO. Both gave essentially the same integral, and the average of the two results for the total cross section is 3.8 $\pm$ 0.6 (stat) $\pm$ 1.3 (sys) μb. This value agrees well with the prediction of the Color Evaporation Model [7].

The $J/\Psi \to ee$ yield versus the number of participants (N_{part}) is shown in Fig. 5 for the pp data and for the $AuAu$ data divided into three centrality bins.

4. Discussion and conclusions

Rather limited conclusions can be drawn from the data in Fig. 5 because of the large statistical and systematic uncertainties associated with this preliminary analysis. We have

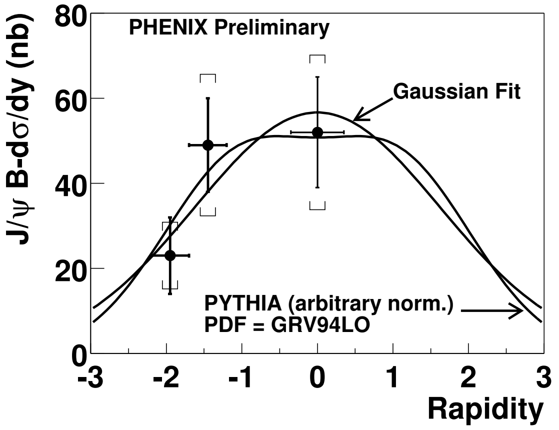

Figure 4. J/Ψ branching ratio times dN/dy vs rapidity for pp Brackets are maximum plausible systematic spreads.

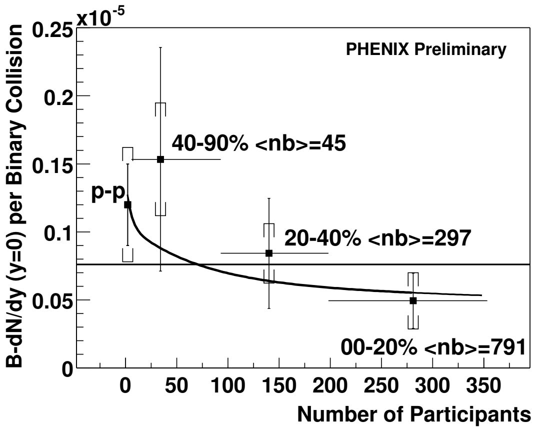

Figure 5. $J/\Psi \rightarrow ee$ branching ratio times dN/dy scaled by N_{binary}. The flat line is the best fit binary scaling value. The curve is a normal nuclear absorption model calculation [8].

fitted a flat line to the data to see if the data are consistent with binary scaling. The best fit, shown in Fig. 5, has a confidence level of 16% based on the statistical uncertainties alone. Thus the binary scaled J/Ψ yields probably trend down with increasing N_{part}, but that is not a strong statement.

We also show in Fig. 5 a comparison of the N_{part} dependence with a calculation from a simple normal nuclear absorption model assuming a 7.1 mb absorption cross section [8]. Here the confidence level is found to be 80%. However we wish to stress that the uncertainties in the data are too large to allow discrimination between any but the most extreme scenarios.

We expect to approximately double the number of measured $J/\Psi \rightarrow ee$ when we add level-2 triggered events to this analysis. We also hope to extract a comparable sample of $J/\Psi \rightarrow \mu\mu$ data at forward rapidity from the existing data set.

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