Transverse momentum distribution of J/ψ produced in Pb - Pb interactions at 158 GeV/c per nucleon.*

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The production of dimuon in Pb-Pb collisions at 158 GeV/c per nucleon has been measured at the CERN SPS in experiment NA50. An anomalous suppression of J/ψ production cross section has been observed in comparison with the value expected from the results obtained in proton and light ion induced reactions. An analysis of the transverse momentum distribution of J/ψ is presented. For J/ψ production, $< p_T^2 >$ values have been calculated as a function of centrality.

1. INTRODUCTION

The suppression of the $c\bar{c}$ charmonia states has been predicted to be an unambiguous signature of Quark-Gluon Plasma (QGP) formation [1]. The NA38 and NA51 collaborations have indeed observed a J/ψ suppression which increases continuously from p–p to central S–U collisions [2,3]. This suppression has been found to be a consequence of J/ψ absorption in nuclear matter [4].

The NA50 collaboration has measured the J/ψ production in Pb–Pb collisions at 158 GeV/c per nucleon [5]. An "anomalous" suppression of the J/ψ production cross section was observed in comparison with the value expected from the results obtained in proton and light ion induced reactions. Different models, such as charmonium absorption by hadronic "comovers" [6] or dissociation by Quark-Gluon Plasma [7,8] were suggested for the interpretation of the experimental results.

The study of the J/ψ transverse momentum (p_T) distributions as a function of transverse energy (E_T) could provide additional information on the nature of the medium formed in heavy ion collisions, as predictions concerning transverse momentum distributions of J/ψ are different in hadronic [9] and Quark Gluon Plasma [10] models. In this report the preliminary experimental results of transverse momentum distributions of J/ψ events obtained by NA50 Collaboration at the CERN SPS are presented based on the 1996 data taking period. The analysis has been carried out on $170 \cdot 10^6$ triggers leading to $\simeq 200000$ J/ψ events.

2. EXPERIMENTAL SET-UP AND ANALYSIS

The NA50 experiment is based on a muon spectrometer, complemented by several detectors. A beam hodoscope is used to detect the incoming ions. Different anti-halo detectors allow to reject those events for which a primary interaction occured upstream the target. The target is segmented, and equipped with interaction detectors allowing to identify the subtarget where the collision occured. An electromagnetic calorimeter measures the neutral transverse energy (E_T) produced in the pseudo–rapidity interval $1.1 \leq \eta_{lab} \leq 2.3$, a zero degree hadron calorimeter measures the energy of the non–interacting beam fragments (E_{ZDC}) and a multiplicity detector measures the charged particle multiplicity in the range $1.65 \leq \eta_{lab} \leq 3.5$. A more detailed description of the layout can be found in [5]. In this work only information from the electromagnetic calorimeter was used for the determination of the interaction centrality.

Events are selected inside a contour in the $E_T - E_{ZDC}$ correlation, corresponding to a 2σ distance from the mean correlation axis [11,12]. Thanks to the excellent 1996 beam conditions, it was possible to get rid of the subtarget identification constraint used for 1995 data [5]. This allows to increase the statistics of the low E_T samples. The dimuons are detected in the kinematical domain $0 \leq y_{cm} \leq 1$, where y_{cm} is the dimuon rapidity in the center of mass frame, and in the range of the decay angle of muon in the Collins-Soper frame $-0.5 \leq cos\theta_{CS} \leq 0.5$. The known dimuon sources in the spectrum of opposite-sign dimuons with $M > 1.5\ GeV/c^2$ are Drell-Yan process (DY), J/ψ and ψ' decays and semi-leptonic decay of pairs of charmed mesons $D\bar{D}$. The spectrum includes also the contribution of background from two muons originating from uncorrelated π and K decays. This background (N_{Bk}^{+-}) is estimated using the numbers (N^{++} and N^{--}) of events in the two like-sign samples of muon pairs, according to the formula [5]: $N_{Bk}^{+-} = 2\sqrt{N^{++}N^{--}}$.

3. EXPERIMENTAL RESULTS

Fig.1 shows the J/ψ production cross-section divided by the Drell-Yan one for different nucleus-nucleus reactions. This ratio, which is free from normalization uncertainties [5], is plotted as a function of L, the corresponding mean thickness of nuclear matter in which the J/ψ can be absorbed after its formation. This quantity is directly related to the sizes of the colliding nuclei and to the impact parameter. All the points are rescaled to the same incident beam momentum (158 GeV/c) and kinematical domain [11,12], using the "Schuler" parametrization for J/ψ, and the "MRS 43" parametrization of the parton distribution functions for Drell-Yan process (which accounts for the $\bar{u}/\bar{d}$ ratio measured by NA51 [13]). The different isospin content of the interacting ions is also taken into account in the rescaling of Drell-Yan cross-sections. As can be seen from Fig.1, the peripheral Pb–Pb points are compatible with the data obtained with lighter ions (from p–p to S–U interactions) whereas more central Pb–Pb data exhibit a clear decrease at L $\simeq$ 8 fm. This "anomalous" J/ψ suppression has already been observed in the 1995 data sample [5].

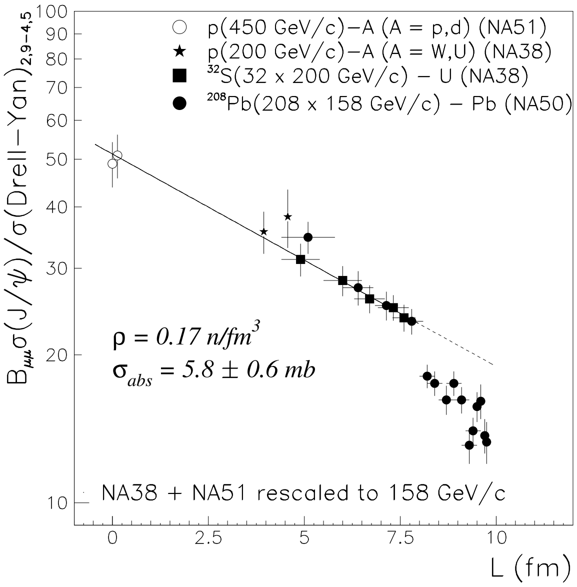

Figure 1. Ratios of J/ψ to Drell-Yan cross sections as a function of L

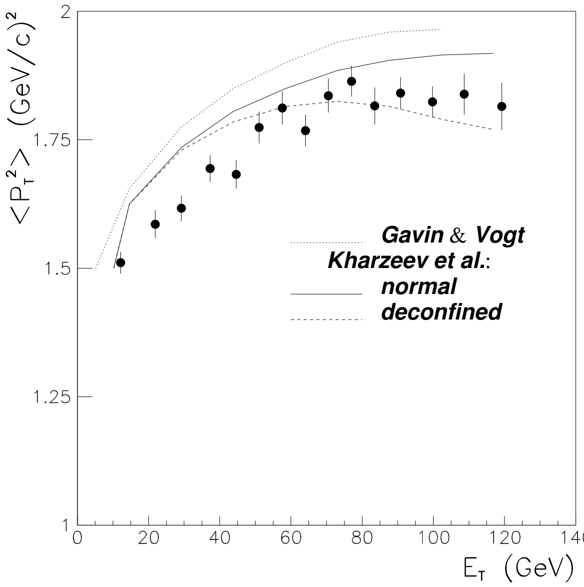

Figure 2. The $< p_T^2 >$ of J/ψ as a function of the tranvverse energy E_T.

4. TRANSVERSE MOMENTUM DISTRIBUTIONS

The study of the J/ψ transverse momentum distributions (p_T) may be a useful tool as predictions concerning p_T behaviour are different in hadronic and Quark-Gluon Plasma models. In order to investigate p_T distributions in Pb–Pb interactions as a function of the centrality, the events are subdivided into 15 subsamples according to the transverse energy of the interaction. The transverse momentum distributions of J/ψ correspond to events in the [2.7–3.5] GeV/c^2 mass region. To correct the spectra for detector acceptance and smearing effects, a 4-dimensional unfolding procedure of the measured data has been developed [14]. In addition, a one-dimensional acceptance and smearing correction method has also been applied to the same data sample. Both procedures account for combinatorial background and for the contribution of the mass continuum in the p_T spectrum corresponding to the J/ψ mass range. The results obtained with these two different correction methods are compatible within errors.

The $< p_T^2 >$ values of the J/ψ p_T distributions obtained with the 4-dimensional method are shown in Fig.2, as a function of E_T. These values increase with the transverse energy, and seem to saturate for the highest E_T intervals [12]. The comparison with theoretical predictions is also shown in Fig.2. Initial state effects such as parton multiple scattering before the formation of the $c\bar{c}$ pair should cause p_T broadening as already observed in p–A collisions [15] and in interactions of light incident ions (oxygen and sulfur) with uranium target nuclei [16]. The model based on the possible formation of Quark-Gluon Plasma [10] predicts that this p_T broadening must be reduced due to the J/ψ suppression in the central part of interaction region. In this case the model predicts a decrease of $< p_T^2 >$ for very high E_T. Both models do not reproduce well the Pb–Pb experimental data, but it is important to notice that these theoretical predictions were done using the available NA38 S–U data at 200 GeV/c, and that the lower momentum of the Pb beam used by NA50 (158 GeV/c) has not been taken into account in these calculations.

5. CONCLUSIONS

From p–p to central S–U collisions, the ratio of the J/ψ production to the Drell-Yan process can be interpreted as a consequence of J/ψ absorption in nuclear matter. Concerning Pb–Pb interactions, an "anomalous" J/ψ suppression is observed for central collisions as compared with the value expected from peripheral Pb–Pb interactions and from experiments using lighter nuclei. The transverse momentum distribution of J/ψ has been studied as a function of the transverse energy released in the interaction. An increase of $< p_T^2 >$ with E_T is observed, as well as a saturation for the highest transverse energy intervals. This behaviour is not well reproduced by the theoretical models, but the calculation do not account for the exact momentum of the incident lead nuclei.

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