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Latest Results on J/ψ Suppression

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Abstract. We present preliminary results on J/ψ production in Pb–Pb collisions at 158 GeV/nucleon, obtained in the analysis of the most recent data sample collected by NA50 experiment in year 2000. The results are compared with an updated absorption curve deduced from new high statistics proton–nucleus data. The measurements reported here confirm the anomalous J/ψ suppression already observed by NA50 from previously collected data samples.

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1. Introduction

Quantum Cromodynamics predicts [1] that, at large density and/or temperature, normal hadronic matter should undergo a phase transition to a new state of deconfined quarks and gluons, the so-called Quark–Gluon Plasma or QGP. Heavy ion collisions are a powerful tool to investigate nuclear matter properties under these extreme conditions and, therefore, sign a possible transition to a QGP state. Among other predictions, it has been anticipated [2] that, if a QGP was formed it could be probed by studying charmonium production as screening of the colour potential, in such a medium, would prevent the formation of $c\bar{c}$ bound states.

NA50 is a high luminosity fixed target experiment at the CERN/SPS, essentially dedicated to the study of dimuon production in Pb–Pb and p–A collisions. The apparatus is designed to study, in particular, the production of J/ψ, via its decay into muon pairs, and its dependence as a function of the centrality of the collision.

In this paper, we report preliminary results on the ratio of the production cross-sections of J/ψ and Drell–Yan muon pairs, noted (J/ψ)/DY, as a function of the centrality of the reaction, obtained from the most recent data sample collected in year 2000. The comparison with an updated nuclear absorption curve, as deduced from data collected with the same apparatus and lighter interacting nuclei, is also presented.

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2. Experimental Setup and Data Selection

The main detector of the NA50 experiment [3] is a muon spectrometer consisting of an air-core toroidal magnet located between two sets of 4 multiwire proportional chambers each. The dimuon trigger of the experiment is provided by 4 scintillator hodoscopes. The centrality of the reaction is estimated with three different detectors: an electromagnetic calorimeter which measures the neutral transverse energy ($E_{\rm T}$) released in the interaction, a zero degree calorimeter measuring the energy of the projectile spectators ($E_{\rm ZDC}$) and a detector measuring the multiplicity of charged particles produced in the collision. A set of counters along the beam line allows beam monitoring and the rejection of pile-up and off-target interactions. Residual parasitic interactions are excluded from the data sample via a simple diagonal band cut applied to the $E_{\rm T}$–$E_{\rm ZDC}$ correlation [4, 5].

A considerable experimental effort was done in year 2000, in order to clarify whether very peripheral Pb–Pb collisions are compatible with the results obtained with lighter interacting nuclei. To avoid Pb–Air interactions, which can potentially contaminate peripheral Pb–Pb events, the target was placed under vacuum up to the pre-absorber. A new target identification algorithm was developed based on the multiplicity detector which led, for very peripheral collisions, to a higher target identification efficiency than reached in previous analyses. Only one Pb target of 9.5% interaction length was used exposed to an average intensity of 1.5×10^7 ions/s. The kinematical domain for dimuon detection, $2.92 < y_{\rm Lab} < 3.92$ and $|\cos\theta_{\rm CS}| < 0.5$, leads to acceptances of the order of 15% for J/ψ and DY in the mass range $2.9 < M_{\mu\mu} < 4.5$ GeV/c^2. After reconstruction and cuts, a final sample of 120 000 J/ψ was used in the analysis.

3. New Results from Year 2000 Data Sample

3.1. Data analysis

The opposite-sign dimuon invariant mass spectrum for masses above 1.5 GeV/c^2, results from the charmonia resonances, J/ψ and ψ', and a muon pair mass continuum originating from semileptonic decays of open charm mesons, from the Drell–Yan process and from the combinatorial background of K and π decays. The latter can be computed from the like-sign muon pairs, i.e. N^{++} and N^{--}, according to the relation $dN^{\rm bkg}/dM = 2\,[(dN^{++}/dM)\,(dN^{--}/dM)\,]^{1/2}$, after applying an off-line cut which forces equal acceptances for positive and negative muons. The invariant dimuon mass spectrum provides the amounts of its various physical components through a fit in the mass range 2.9 GeV/c^2 to 8.0 GeV/c^2. The shapes of each of the contributions used in this fit are determined via Monte Carlo and spectrometer simulation, using the same selection criteria and reconstruction program as for real data. The fit provides the ratio of events due to J/ψ and to the DY mechanism and allows to compute the ratio $(B_{\mu\mu}\sigma_{{\rm J}/\psi})/\sigma_{\rm DY}$. The DY cross-section is used as a reference since, as expected, it indeed exhibits linear scaling with A$\times$B, the product of the target and projectile mass numbers, and goes like the number of elementary nucleon–nucleon collisions in the interaction. Moreover, most of the systematic errors cancel out in the ratio of cross-sections which is insensitive, in particular, to the absolute incident flux uncertainty.

3.2. J/ψ *normal nuclear absorption*

In order to check whether Pb–Pb peripheral collisions follow the J/ψ absorption behaviour seen in lighter systems, additional samples of high statistics data were collected to study p–nucleus interactions with improved accuracy. (J/ψ)/DY measurements obtained from these new data have been fitted with a Glauber parametrisation together with previous pp and pd results from experiment NA51 at 450 GeV [6] and with S–U results from experiment NA38 at 200 GeV [7,8]. All these data have been collected with the same dimuon spectrometer as used by experiment NA50. Results are plotted in Fig. 1 as a function of the average path length of nuclear matter, L, crossed by the $c\bar{c}$ pair after its formation. The continuous line represents a Glauber calculation fitted to the data and leading to an absorption cross-section of 4.3 ± 0.5 mb [9].

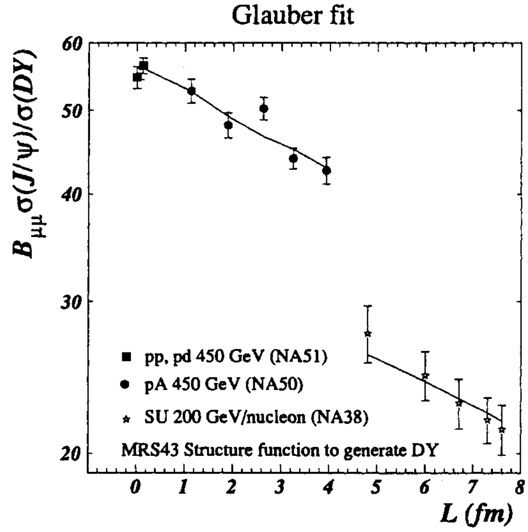

Fig. 1. The ratio $(J/\psi)/DY_{2.9-4.5}$ vs. L. The kinematical domains at 450 and 200 GeV are different. All data are analyzed using the MRS A parton distribution functions. The curve stands for a Glauber fit giving $\sigma_{abs} = 4.3 \pm 0.5$ mb

3.3. The ratio $(J/\psi)/DY_{2.9-4.5}$ *as a function of centrality*

Preliminary results from the Pb–Pb 2000 data are presented in Fig. 2, as a function of the neutral transverse energy. The Drell–Yan cross-section is extracted by fitting the data with the MRS A (LQ) parton distribution functions. Results from three

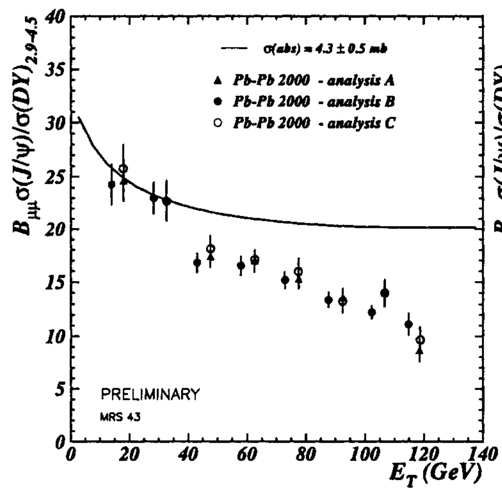

Fig. 2. The ratio $(J/\psi)/DY_{2.9-4.5}$ as a function of E_T

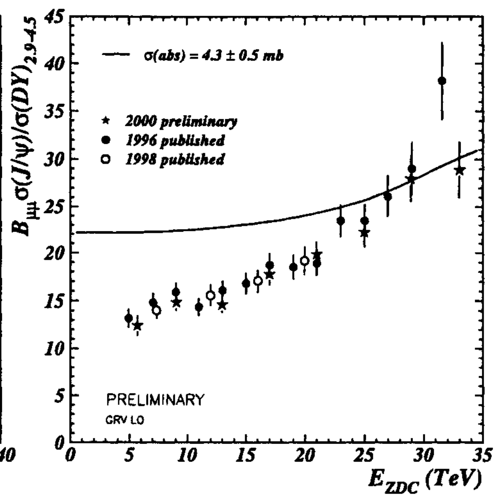

Fig. 3. The ratio $(J/\psi)/DY_{2.9-4.5}$ as a function of E_{ZDC} and comparison with previous years

different analyses, using different selection criteria, E_T binnings and fitting methods agree within few percent. Peripheral Pb–Pb data follow the normal absorption as deduced from the p–A and S–U measurements. The three analyses show that the ratio $(J/\psi)/DY$ departs from the hadronic absorption curve at mid-centrality and steadily decreases for the most central reactions. The Pb–Pb 2000 preliminary results for the ratio $(J/\psi)/DY_{2.9-4.5}$ as a function of the forward energy, E_{ZDC}, are shown in Fig. 3, together with our previous 1996 and 1998 results. All published analyses are in the same conditions as our preliminary 2000 measurements and a coherent direct comparison can thus be done. In the specific case of these analyses, Drell–Yan cross-section is fitted using the GRV 92 LO parton distribution functions. The 1996 data could be contaminated by some Pb–Air interactions for the most peripheral events. The suppression pattern observed here is similar to the one seen as a function of E_T: departure from the normal absorption curve at mid-centrality followed by a steady decrease with increasing centrality.

3.4. A new Drell–Yan reference

For normalization purposes, the Drell–Yan contribution has been usually evaluated in the mass region $2.9 < M_{\mu\mu} < 4.5$ GeV/c^2. As a consequence, when comparing data sets analyzed with different parton distribution functions, differences of at most 10% do appear. This dependence is overcome by normalizing the J/ψ cross-section to a Drell–Yan cross-section measured in the range $4.2 < M_{\mu\mu} < 7.0$ GeV/c^2, where Drell–Yan is the only contribution to the invariant mass spectrum. $(J/\psi)/DY_{4.2-7.0}$ is practically independent of the particular set of pdf used. The feature is illustrated in Fig. 4 which displays our results from the 2000 data, analyzed with GRV 92 LO and MRS A (LQ), and normalized to the new Drell–Yan mass domain. The J/ψ suppression pattern remains the same but the overall normalization is obviously changed.

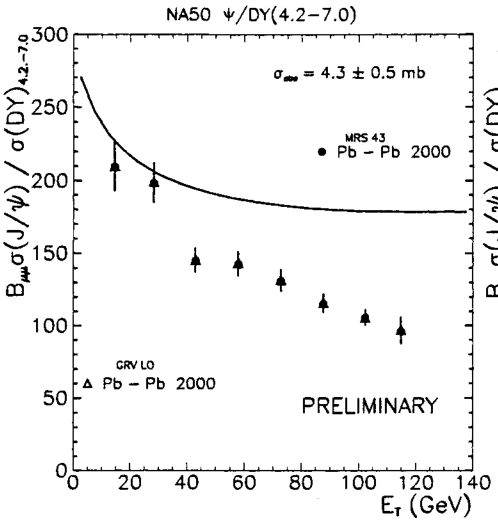

Fig. 4. The ratio $(J/\psi)/DY_{4.2-7.0}$ as a function of E_T

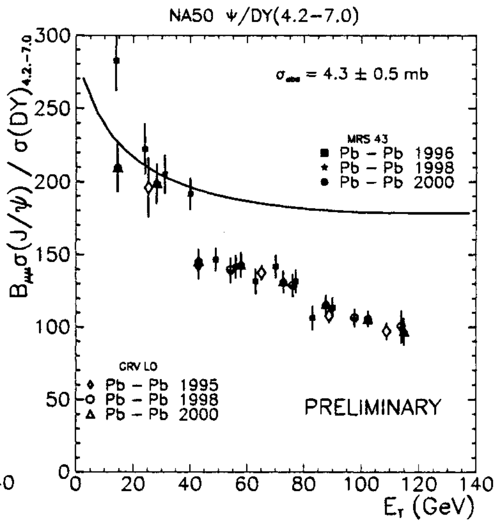

Fig. 5. The ratio $(J/\psi)/DY_{4.2-7.0}$ for all NA50 Pb–Pb data

Finally a coherent comparison between the preliminary 2000 results and all our previous published measurements as a function of E_T can be done (see Fig. 5). Except for the most peripheral 1996 data, potentially contaminated by Pb–Air interactions, all analyses agree reasonably well. The abnormal J/ψ suppression pattern is present in all the Pb–Pb data, with a departure from normal nuclear absorption at mid-centrality followed by a steady decrease of $(J/\psi)/DY$ with increasing centrality.

4. Conclusions

The most recent NA50 Pb–Pb data sample has allowed to investigate, under improved experimental conditions, the J/ψ suppression pattern. Additional high statistics proton–nucleus data together with our previous NA51 and NA38 results have led to a more accurate determination of the "normal" absorption cross-section as deduced from lighter interacting nuclei. Peripheral Pb–Pb interactions are compatible with the "normal" absorption. All Pb–Pb data samples agree fairly well, when coherently compared. They exhibit the same suppression pattern either using E_T or E_{ZDC} as a centrality estimator: a departure from the normal nuclear absorption pattern at mid-centrality followed by a steady decrease for more central interactions.

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Notes

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References

1. C. Bernard et al., *Phys. Rev.* **54** (1996) 4585 and references therein.
2. T. Matsui and H. Satz, *Phys. Lett.* **B178** (1986) 416.
3. M.C. Abreu et al. (NA50 Collaboration), *Phys. Lett.* **B410** (1997) 327.
4. M.C. Abreu et al. (NA50 Collaboration), *Phys. Lett.* **B410** (1997) 337.
5. C. Quintans, *PhD Thesis*, Instituto Superior Técnico, Lisbon, 2002.
6. M.C. Abreu et al. (NA51 Collaboration), *Phys. Lett.* **B438** (1998) 35.
7. M.C. Abreu et al. (NA38 Collaboration), *Phys. Lett.* **B449** (1999) 128.
8. M.C. Abreu et al. (NA38 Collaboration), *Phys. Lett.* **B466** (1999) 408.
9. B. Alessandro et al. (NA50 Collaboration), *Phys. Lett.* **B553** (2003) 167.