Charmonium production in Pb–Pb collisions

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The NA50 Collaboration studies the J/ψ, ψ' and Drell–Yan production via their dimuon decay in Pb–Pb interactions at 158 GeV per nucleon at the CERN SPS: the most recent results on charmonium production are presented here.

1. INTRODUCTION

The NA50 experiment studies at the CERN SPS the production of vector meson resonances in high energy heavy–ion interactions via their $\mu^+\mu^-$ decay as a function of the collision centrality. The aim of the experiment is the study of the nuclear matter under extreme conditions of energy density in order to get evidence for the formation of a new state of matter, the Quark–Gluon Plasma (QGP). This contribution summarizes the 1996 charmonium results, recently published[1], and reports the preliminary results obtained from the data collected in 1998 on J/ψ in Pb–Pb interactions at 158 GeV per nucleon.

2. EXPERIMENTAL RESULTS

2.1. The "standard" analysis

Since the Drell-Yan cross–section scales as the number of primary nucleon–nucleon collisions from pp up to PbPb collisions[2,3] without showing sizeable nuclear effects this process can be used as a reference. In this way the J/ψ over Drell-Yan ratios are free from all systematic errors and the behaviour of the J/ψ production cross section can be investigated as a function of the centrality of the collision. Figure 1 shows the measured J/ψ to Drell–Yan ratio as a function of the neutral transverse energy E_T for the 1996 Pb–Pb data sample. All values are given at the actual beam momentum of 158 GeV/c and there is no isospin correction to the Drell-Yan cross–section. The full line corresponds to the fit, made in the frame of a Glauber model, to the lighter interacting systems shown in Figure 2 and it describes the ordinary nuclear absorption of charmonia ($\sigma_{abs} = 6.4 \pm 0.8$ mb). It is clear from the figure that the central Pb-Pb data exhibit a significant departure from this behaviour and in particular a drop of yield is visible at $E_T \simeq 45$ GeV (where the E_T resolution is about 5 GeV) corresponding to an impact parameter $b \simeq 8$ fm. It is the first time that the anomalous suppression pattern can be observed within the same data sample, without the need of beam energy and isospin corrections necessary for the comparison of different data sets.

In order to compare different systems, characterized by different kinematical domains and in some cases also different experimental E_T range, the variable L has been introduced in the past[4]. L is defined as the geometrical mean path length of the produced $c\bar{c}$ state

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through nuclear matter and is computed via a Monte-Carlo program. The ratio of J/ψ to Drell–Yan cross sections in Pb–Pb interactions is plotted in Figure 2 as a function of L in each of the 15 E_T bins (1996 data) and compared with previous results from NA38 and NA51 experiments. All 450 and 200 GeV/c data presented in this figure are rescaled to 158 GeV/c using the Schuler parametrisation[5] and the measured Drell–Yan cross sections have been corrected for isospin effects. The full line is a simple exponential fit of $e^{-\rho_o \bar{L} \sigma_{abs}}$ to the proton and sulphur data where ρ_0=0.17 fm^{-3} is the nuclear matter average density. The exponential fit leads to $\sigma_{abs} = 5.8 \pm 0.7$ mb which can be considered as a good first order approximation of the absorption cross section of charmonia in nuclear matter. It should be noted that the peripheral Pb-Pb points can be described by the mentioned exponential behaviour, while a clear additional suppression is visible for the more central Pb-Pb collisions.

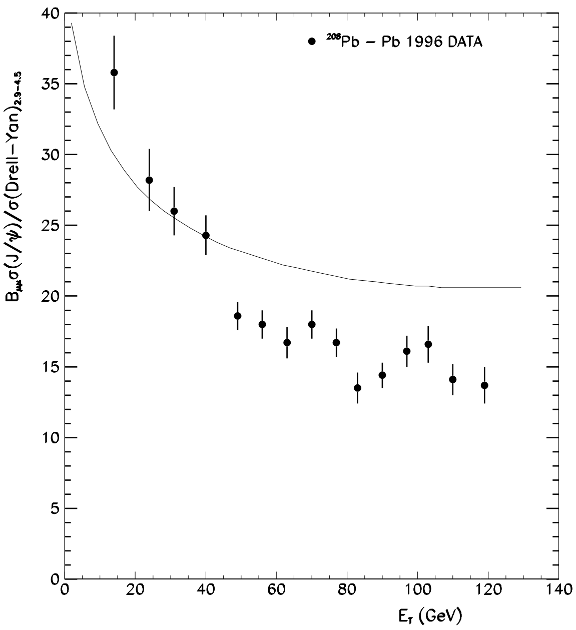

Figure 1. The $B_{\mu\mu}\sigma_{J/\psi}/\sigma_{Drell-Yan}$ ratio versus E_T.

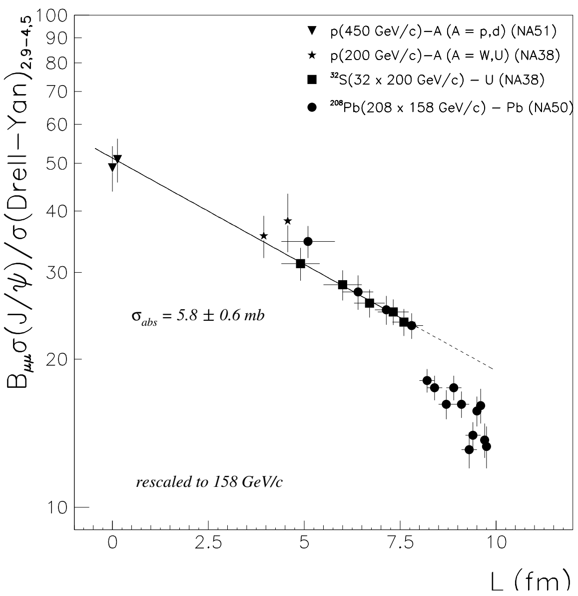

Figure 2. The $B_{\mu\mu}\sigma_{J/\psi}/\sigma_{Drell-Yan}$ ratio versus L.

2.2. The "minimum bias" analysis

In order to overcome the statistical fluctuations of the J/ψ over Drell-Yan ratio, essentially due to the small number of Drell-Yan events, an alternative independent analysis has been developed[1]. The number of Drell-Yan events is now estimated starting from the big sample of minimum bias events collected with a beam trigger which fires when hadronic energy is measured in the zero degree calorimeter; only the J/ψ sample of events is in common with the standard analysis. Figure 3 shows, as a function of centrality, the comparison of the ratios of the J/ψ to Drell–Yan cross-sections as obtained in the usual analysis (full circles) and the cross-sections ratio $B_{\mu\mu}\sigma_{J/\psi}/\sigma_{Drell-Yan^{\star}}$ based on the directly counted J/ψ and minimum bias events (empty circles), affected by much lower statistical fluctuations. The comparison of these two independent analysis establishes that the drop can only be due to a reduced J/ψ production cross-section.

The 1998 run has been devoted to clarify the results in the high E_T region, since the 1996 data seems to be affected, in this E_T range, by re-interaction event contamination due to the thickness of Pb target (30% of an interaction length in 1996, 7% of an interaction length in 1998). In Figure 4 the preliminary 1998 results obtained with the minimum bias analysis are shown with the 1996 ones obtained with both the standard and minimum bias analysis. In the upper end of the E_T range only the 1998 results are shown. This data confirm the behaviour observed in the 1996 data but exhibit a further suppression for the more central events.

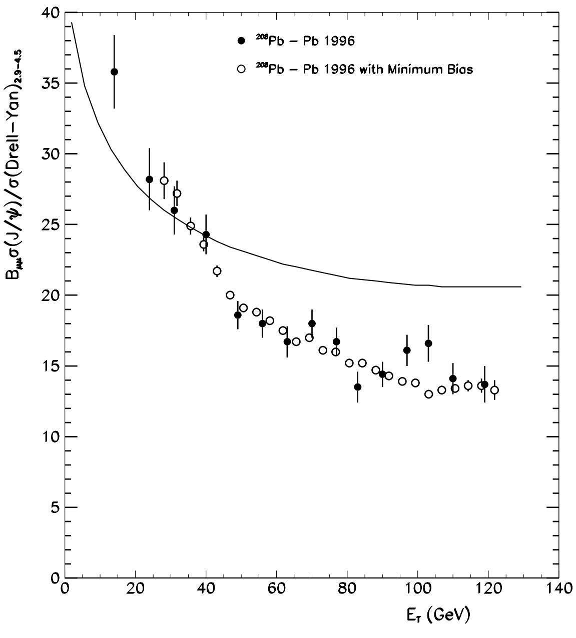

Figure 3. Comparison of the ratio $B_{\mu\mu}\sigma_{J/\psi}/\sigma_{Drell-Yan}$ and $B_{\mu\mu}\sigma_{J/\psi}/\sigma_{Drell-Yan^{\star}}$ for 1996 data.

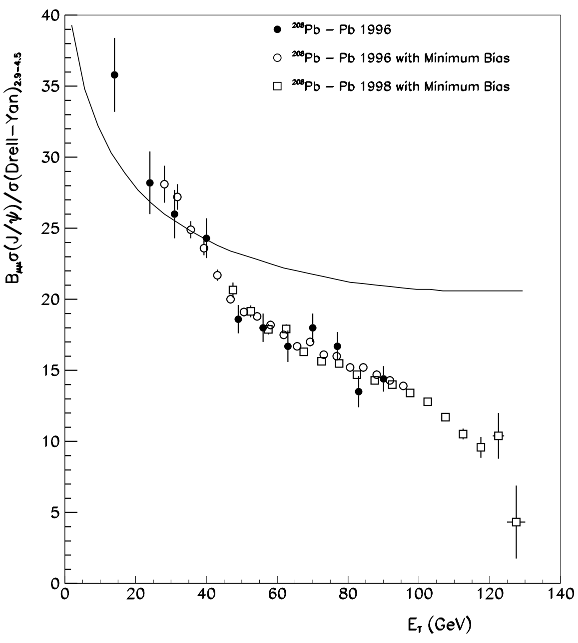

Figure 4. The $B_{\mu\mu}\sigma_{J/\psi}/\sigma_{Drell-Yan}$ ratio versus E_T for 1996 and 1998 data.

REFERENCES

1. M.C.Abreu et al., *Phys. Lett.* B **450**, 1999 (456).
2. M.C.Abreu et al., *Phys. Lett.* B **410**, 1997 (327).
3. M.C.Abreu et al., *Phys. Lett.* B **410**, 1997 (337).
4. C. Gerschel and J. Hufner, *Z. Phys.* C **56**, 1992 (71).
5. G.A. Schuler, CERN–TH 7170/94 (hep–ph/9403387), 1994.