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Latest results on J/ψ anomalous suppression

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Abstract. The NA50 experiment deals with Pb–Pb collisions at 158 GeV/nucleon at the CERN SPS accelerator. The J/ψ production is studied through the muon decay channel, using the Drell–Yan dimuons as a reference. New results based on recent analyses, from data taken with improved experimental conditions and using different centrality estimators, are presented and compared to an update of those already obtained from previous data samples. The stepwise pattern of the anomalous J/ψ suppression as a function of centrality, already present in these previous results, is confirmed. This observation could be a fingerprint of the theoretically predicted melting of charmonia resonances in a deconfined quark–gluon plasma.

Keywords. J/ψ anomalous suppression; quark-gluon plasma; deconfinement.

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1. Introduction

NA50 is a dimuon experiment searching for specific signals of deconfinement, namely the predicted suppression of charmonia production. Indeed, it has been predicted [1] that the $c\bar{c}$ bound states are prevented to be formed by the colour screening potential in the very dense medium undergoing a phase transition to a deconfined medium of quarks and gluons.

2. Experimental set-up and data selection

The NA50 apparatus [2] mainly consists of a muon spectrometer, a segmented active target and three independent centrality detectors: an electromagnetic calorimeter which measures the neutral transverse energy (E_{T}) produced in the interaction, a zero degree calorimeter measuring the energy released by the spectator nucleons (E_{ZDC}) and a silicon strip multiplicity detector.

In this analysis we use data taken in 1996 and 1998 with a lead beam impinging on a Pb target, as well as the new p–A data of 1996–2000 ($A \equiv$ Be, Cu, Al, Ag, W, Pb) taken at two different beam intensities.

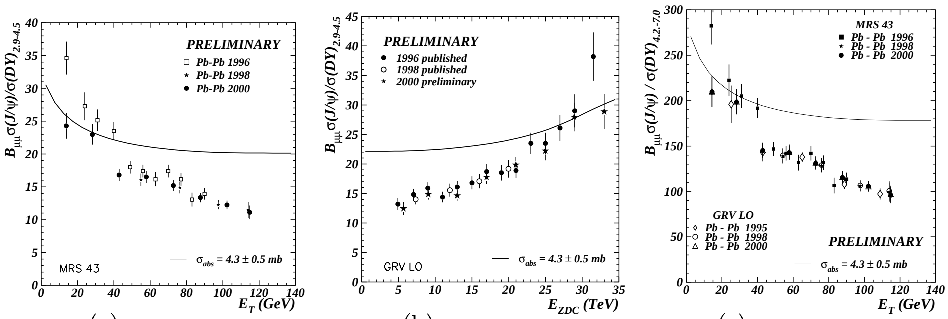
The kinematical domain used for dimuon detection, $2.92 \leq y_{\mathrm{lab}} \leq 3.92$ and $|\cos\ \theta_{\mathrm{CS}}| < 0.5$ leads to acceptances of the order of 15%, in the mass region of interest. The centrality detectors cover the following rapidity domains: e.m. calorimeter, $1.1 < \eta_{\mathrm{lab}} < 2.3$; zero degree calorimeter, $\eta_{\mathrm{lab}} > 6.3$; multiplicity detector, $0.82 < \eta_{\mathrm{lab}} < 4.18$.

The J/ψ is detected via its decay into muon pairs. Combinatorial background, due to π and K decays, is estimated from like-sign pairs [2], using $N_{\mathrm{BG}} = 2\sqrt{N^{++}N^{--}}$. The muon pairs selected for the analyses satisfy the standard NA50 criteria [3].

3. J/ψ production analyses

A study of Drell–Yan behaviour, based on our data on p–p, several p–A, S–U and Pb–Pb systems, proves that its cross-section behaves normally and is proportional to the number of elementary nucleon–nucleon collisions [4]. Thus, it can be used as a J/ψ reference.

A new J/ψ systematic study was performed using the present NA50 high statistics p–A data [5] together with our previous data from lighter systems, namely p–p and p–d from NA51 [6] and S–U from NA38 [7]. Using Glauber model calculations to describe the data, one extracts an absorption value of the $c\bar{c}g$ state in nuclear



(a) (b) (c)

Figure 1. (**a**) J/ψ/DY as a function of $E_{\rm T}$ for 2000, together with previous data; (**b**) Same for J/ψ/DY as a function of $E_{\rm ZDC}$; (**c**) J/ψ/DY as a function of $E_{\rm T}$ – new analysis using the directly measured yield $M_{\mu\mu} > 4.2$ GeV/c^2. The superimposed curves represent the absorption fit to our lighter systems.

matter of $\sigma_{\rm abs} = 4.3 \pm 0.5$ mb. It is the normal J/ψ suppression, and constitutes the baseline for Pb–Pb studies.

Figure 1a shows the J/ψ production cross-section, normalised to the Drell-Yan one, as a function of the neutral transverse energy $E_{\rm T}$ released in the interaction, for the 2000 data, together with all previous data taking periods. Some of them have been re-analysed in order to meet the 2000 analysis criteria. All data show agreement within a few per cent. Also superimposed is the normal J/ψ absorption curve, as explained above. Whereas the more peripheral Pb–Pb points lie on it, the mid-central ones show the anomalous J/ψ suppression: a departure at $\sim$40 GeV with no saturation at high $E_{\rm T}$.

The J/ψ production, normalised to Drell–Yan cross-section, is also studied as a function of an independent centrality variable, $E_{\rm ZDC}$, given by a different detector, the forward hadronic calorimeter (figure 1b). The 2000 data and all previously published data show good agreement. Once again, a clear departure from our absorption fit at mid-centrality values, not saturating at high centrality, is seen.

In the standard J/ψ/DY analysis Drell–Yan was measured above 4.2 GeV/c^2, where it constitutes the only component, and then re-evaluated underneath J/ψ, together with the other physics ingredients, using some structure function. Changing it could lead to a 10% difference in the Drell–Yan reference (defined in $2.9 < M_{\mu\mu} < 4.5$ GeV/c^2). With a new analysis method, using the directly measured yield ($4.2 < M_{\mu\mu} < 7.0$ GeV/c^2), one obtains a unique result. In this way, J/ψ/DY results become independent of the parton distribution functions used and the compatibility among all Pb–Pb data becomes very good (figure 1c).

4. Conclusions

Two different analyses have been performed for 2000 data (for which target region was placed in vacuum): J/ψ cross-section was normalised to the Drell–Yan one as a function of two independent centrality variables (the transverse energy measured with the electromagnetic calorimeter, and the very forward energy evaluated with the zero degree calorimeter). They fairly agree with all analyses of previous data taking periods (1995, 96, 98) and also exhibit the already observed features: departure from the absorption curve at mid-centrality (e.g., $E_{\mathrm{T}} \sim$ 40 GeV) and no saturation at high centrality.

When using, as a reference for J/ψ, dimuon masses above 4.2 GeV/c^2, where the only ingredient is Drell–Yan, the results are no more PDF dependent and very good agreement is observed among all Pb–Pb data.

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