Charmonia suppression in p–A collisions at 450 GeV/c; new results from NA50

E. Scomparin[10] - NA50 collaboration

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Drell-Yan, J/ψ and ψ' production in proton-induced collisions on Be, Al, Cu, Ag and W targets has been studied by the NA50 collaboration at the CERN SPS. Results on absolute cross sections and cross section ratios are presented. We show that J/ψ suppression in proton-nucleus and in sulphur-uranium collisions can be understood in terms of nuclear absorption and there is no indication of an additional suppression mechanism in S-U collisions compared to p-A.

The observation of the anomalous J/ψ suppression [1] represents today the key signature of QGP formation at SPS energies. However, dissociation processes at the hadronic level can also give a sizeable J/ψ suppression, making somewhat more complicated the interpretation of the experimental results. The study of J/ψ production in p-A collisions allows to investigate the absorption mechanisms of the $c\bar{c}$ state in its path across the nucleus. A comparison of p-A data with nucleus-nucleus data helps in disentangling the different sources of hadronic absorption: the nuclear absorption, present in all nuclear collisions, and the interaction of the J/ψ with comoving secondary hadrons, which could play a role in nucleus-nucleus interactions. The size of this second effect is up to now poorly known, mainly because of the uncertainty in the theoretical calculation of the J/ψ-hadron cross section.

To investigate these topics, the NA50 collaboration has performed a study of J/ψ production in p-A collisions at 450 GeV/c incident energy on five nuclear targets, namely Be, Al, Cu, Ag and W. Thanks to the high statistics collected, it has also been possible to study the nuclear dependence of ψ' and high-mass Drell-Yan production. The standard NA50 muon spectrometer [2] has been used. Data have been collected with a primary proton beam from the CERN SPS. The chosen beam intensity was around $2{\cdot}10^8$ p/s, to avoid event pile-up in the spectrometer, which could spoil the reconstruction efficiency. The luminosity has been measured by a set of 3 independent argon counters, calibrated at low beam intensity and whose linearity was checked up to 10^{10} p/s. The selection $-0.4< y_{cm} <0.6$ and $-0.5<\cos\theta_{CS} <0.5$, corresponding to the kinematical window of the spectrometer's acceptance, has been applied to reconstructed muon pairs. The number of J/ψ, ψ' and Drell-Yan events have been estimated by means of a fit on the measured invariant mass spectra. The combinatorial background, due to uncorrelated decays of pion and kaon pairs, has been estimated from the measured $\mu^+\mu^+$ and $\mu^-\mu^-$ spectra. The target-out contribution has been calculated with dedicated empty target data taking. Details on the data analysis procedure can be found in Ref. [3,4]. In Fig. 1 we plot, as a function of the mass number A, the J/ψ and ψ' cross sections per target nucleon. The NA51 results for p-p and p-d interactions at 450 GeV/c [5] are also shown. The measured cross sections have been fitted with the function: $\sigma_{p-A} = \sigma_{p-p} \cdot A^{\alpha}$. The NA51 points have not been included in the fit as this parametrisation is known to fail for the lightest nuclear targets [6]. We get $\alpha_{J/\psi} = 0.925 \pm 0.002$(stat)$\pm$0.018(syst), $\alpha_{\psi'} = 0.913 \pm 0.015$(stat)$\pm$0.018(syst), indicating, as expected, a sizeable nuclear absorption for charmonia. Concerning Drell-Yan, a fit to the measured cross section per target nucleon, integrated in the invariant mass region $2.9 \leq M \leq 4.5$ GeV/c^2, gives $\alpha_{DY} = 0.993 \pm 0.016$(stat)$\pm$0.019(syst). The isospin dependence of Drell-Yan production has been corrected using the MRS (A) low Q^2 $\overline{MS}$ set of parton distribution functions. An α factor compatible with one means, confirming theory predictions [7], that for this process nuclear effects are negligible in NA50 kinematic domain. Therefore, Drell-Yan can be safely used as a reference process for the study of charmonia production.

Ratios of cross sections are appealing quantities from an experimental point of view, since they are free from systematic errors connected with luminosity measurements and determination of various efficiencies, which cancel in the ratio. Moreover the use of Drell-Yan as a reference process is useful because the cross section for this hard process is proportional to A and therefore to the number of nucleon-nucleon collisions. In this way the ratio $\sigma_{J/\psi}/\sigma_{DY}$ is equivalent to $\sigma_{J/\psi}/A$. The drawback of the method is the introduction of larger statistical errors because of the relatively small Drell-Yan statistics. In Fig. 2 we plot the ratios $B_{\mu\mu}\,\sigma_{J/\psi}/\sigma_{DY}$ and $B'_{\mu\mu}\,\sigma_{\psi'}/\sigma_{DY}$, where the Drell-Yan cross section has been integrated over the mass range $2.9 \leq M \leq 4.5$ GeV/c^2. As for the absolute cross sections plot, the NA51 points are shown but not included in the A^{α} fit. Assuming α_{DY}=1, we get from the fit of the cross section ratios $\alpha_{J/\psi} = 0.934 \pm 0.014$ and

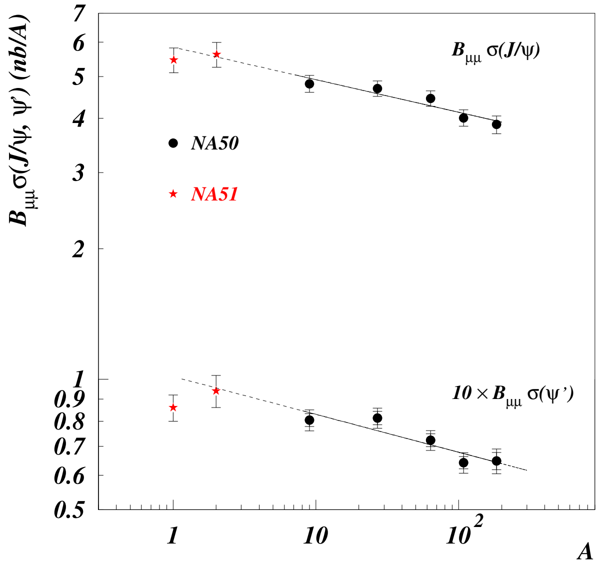

Figure 1. Charmonia cross sections for p-A collisions at 450 GeV/c incident energy.

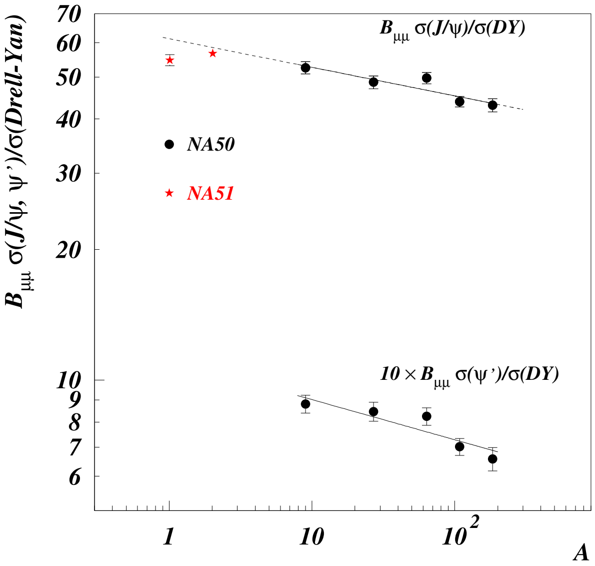

Figure 2. The ratios $J/\psi/DY$ and ψ'/DY vs mass number A.

$\alpha_{\psi'} = 0.907 \pm 0.020$. As for absolute cross sections, data indicate a slightly larger nuclear absorption for the ψ' compared to the J/ψ. This appears also in the direct study of the $\sigma_{\psi'}/\sigma_{J/\psi}$ ratio. A direct fit to $\sigma_{\psi'}/\sigma_{J/\psi}$ vs A gives in fact: $\Delta\alpha = \alpha_{J/\psi} - \alpha_{\psi'} = 0.029 \pm 0.014$.

Nuclear absorption of charmonia, parametrized in the study of proton-nucleus collisions through the quantity α, plays a significant role also in nucleus-nucleus interactions, where a second hadronic suppression mechanism, comover absorption, could be present. A variation in the slope of charmonia cross section vs nuclear size, between p-A and A-A collisions, would indicate the onset of such a mechanism. To investigate this topic, the ratios $J/\psi/DY$ can be safely used, since Drell-Yan is known to scale with the number of N-N collisions also in nucleus-nucleus interactions [8]. The comparison has been usually carried out using as independent variable L [9], the mean length of nuclear matter seen by the pre-resonant $c\bar{c}$ state [10] that will form the J/ψ. In this framework the slope of $J/\psi/DY$ vs L is directly connected, in a first approximation, with the effective cross section for J/ψ interaction. In Fig. 3 we plot with open symbols the ratio $J/\psi/DY$ versus L for the p-A collisions studied in this work and for S-U collisions at 200 GeV/nucleon, studied by the NA38 collaboration [11].

However, a direct comparison of the slopes of $J/\psi/DY$ vs L in p-A and S-U is not meaningful, since it is known that a sizeable fraction of the observed J/ψ yield comes from radiative decays of the χ_c and of the ψ'. While the nuclear dependence of χ_c production is unknown, the ψ' yield has been measured both in p-A (this work) and S-U [11] and its contribution to J/ψ production can be removed. The $J/\psi/DY$ data, corrected for the ψ' contamination, are shown as closed symbols in Fig. 3. If we now fit separately the p-A and S-U points we get a slope difference between the two samples of data corresponding to $\Delta\sigma_{\psi N}^{SU-pA} = \sigma_{J/\psi\, N}^{SU} - \sigma_{J/\psi\, N}^{pA} = (0.9 \pm 2.2)$ mb. Since the difference between the two

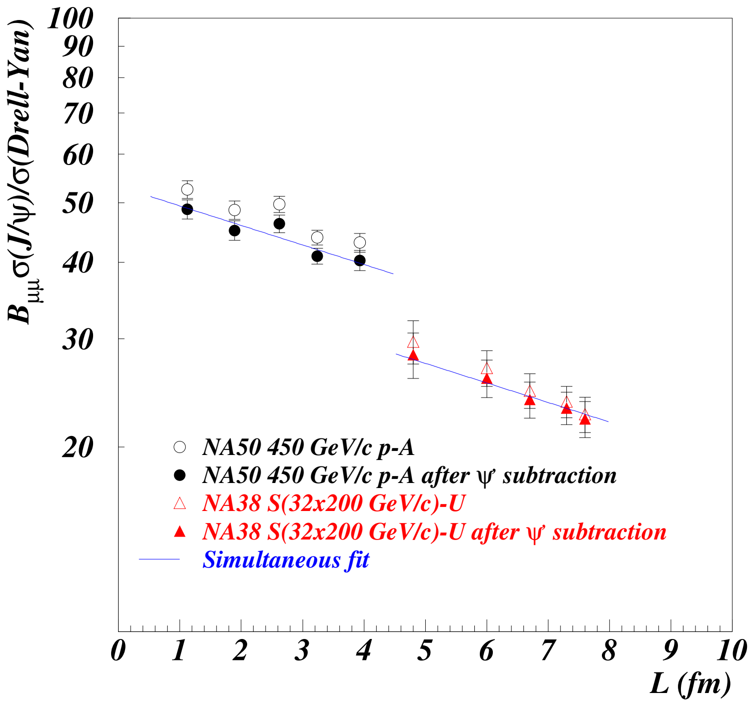

Figure 3. The $J/\psi/DY$ ratio in p-A and S-U collisions, before and after the subtraction of J/ψ contamination from the ψ' decay.

cross sections is compatible with zero, we can fit simultaneously the two data sets with a common slope, obtaining a $\chi^2/d.o.f.$=0.55. The result of such a fit, shown in Fig. 3, indicates that the slope of p-A and S-U points are fully compatible and therefore no additional source of J/ψ suppression has to be introduced to explain sulphur-uranium data compared to proton-nucleus.

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