NA50 final results on charmonia suppression

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Abstract. The last results from the NA50 experiment on charmonia production in Pb-Pb interactions at 158 GeV/c per nucleon are presented. A strong J/ψ suppression is observed, which increases with the centrality of the collisions.

The J/ψ production is seen to be anomalously suppressed starting at mid-centralities, when compared to a reference taken from proton-induced collisions. The most recent developments on the determination of this normal absorption curve are explained. It is also shown that for sulphur-induced reactions there is full agreement with the extrapolated normal p-A behaviour.

The suppression of $\psi\prime$ production in heavy ion collisions (Pb-Pb and S-U) is also presented. It is seen to increase with the centrality of the collisions, and to be significantly stronger than the one measured in proton-induced reactions.

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1. Introduction

The prediction that the J/ψ vector-meson is suppressed in a quark gluon plasma medium is investigated by the NA50 experiment from CERN. The ultra-relativistic Pb-Pb collisions are believed to form a very dense medium, whose cooling and subsequent hadronization can be studied by means of the produced correlated muon pairs. The NA50 experimental apparatus consists of beam detectors, a multiplicity detector(MD), an electromagnetic (EC) and a very forward hadronic calorimeter (ZDC), followed by a dimuon spectrometer. The latter includes a carbon core absorber and an air-core toroidal magnet in between two sets of multiwire proportional chambers and trigger hodoscopes. For the data taking periods of 1998 and 2000, the MD was used as a vertex detector, particularly sensitive to the peripheral lead-lead interactions. For the 2000 data, the last and best period (from the point of view of data quality), the target region up to the EC central hole was put under vacuum, in order to avoid spurious lead-air interactions. The strong suppression of the J/ψ production in central lead-lead collisions, observed for the first time in the 1995 NA50 data [1], was confirmed by all the following sets of data available.

2. J/ψ suppression in Pb-Pb

In order to study the J/ψ suppression as a function of centrality, NA50 has 3 independent centrality estimators: the neutral transverse energy measured by the EC, the multiplicity of charged particles from the MD, and the energy of the spectator nucleons given by the ZDC.

A reference process is also needed to study the centrality dependent charmonia suppression. The Drell-Yan dimuons are used as a reference, since this is a well-known process that scales with the number of nucleon-nucleon collisions, from p-p up to Pb-Pb, as was experimentaly shown [2]. The number of Drell-Yan events is obtained from the same dimuon mass spectra as the J/ψ events, with the same selection criteria, and thus most of the systematical errors calcel when doing the two processes ratio. The drawback of using Drell-Yan is its relatively poor statistics.

3. The normal p-A J/ψ absorption

The J/ψ suppression in lead-lead collisions increases with the centrality. While this is partly expected from nuclear absorption mechanisms, already observed in proton-nucleus collisions (the so-called normal nuclear absorption), there is an anomalous amount of suppression in Pb-Pb, setting in from mid-centralities on. The normal absorption cross-section, σ^{ψ}_{abs}, of the J/ψ vector-meson has been previously calculated from the high statistics NA50 p-A data at 450 GeV/c, together with NA51 p-p and p-d data and NA38 S-U at 200 GeV/nucleon data. Although these data sets had different beam energies, it was shown that their independently extracted σ^{ψ}_{abs} are compatible within errors, thus allowing for a J/ψ/DY simultaneous fit. Using the Glauber formalism, we obtain $\sigma^{\psi}_{abs} = 4.18 \pm 0.35$ mb, and a rescaling factor to go from 450 to 200 GeV. The fit parameters are used to compute the normal nuclear absorption curve, where we include the necessary rescale from 200 to 158 GeV/nucleon [3].

The normal absorption curve can be obtained in an alternative way, extracted only from proton-nucleus data [4]. In this new procedure, the high statistics NA50 J/ψ/DY p-A data at 450 and 400 GeV/c and the NA51 p-p and p-d at 450 GeV/c are fitted simultaneously, the result of the Glauber fit being $\sigma^{\psi}_{abs} = 4.18 \pm 0.35$ mb (non-coincidently the same as in the previous method). The normalization of the absorption curve is obtained by taking additionaly to these data sets the low statistics NA38 and NA3 p-A data at 200 GeV/nucleon, and by redoing the Glauber fit of the $B_{\mu\mu}\sigma(\mathrm{J}/\psi)$ as a function of A, with fixed σ^{ψ}_{abs} (see figure 1). The smaller J/ψ rescaling factor to go from 200 to 158 GeV is obtained from the Schuler parameterization (while for the Drell-Yan it is obtained theoretically).

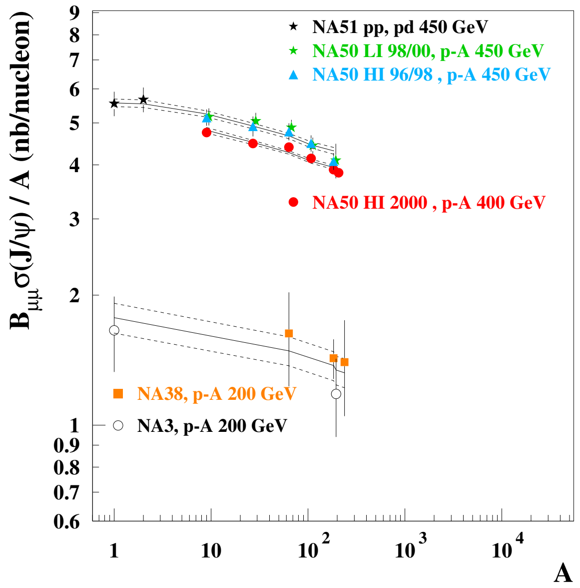

Figure 1. J/ψ absolute cross-sections in proton induced collisions, at 450, 400 and 200 GeV/c. Fit imposing the slope extracted from p-A data at 450/400 GeV/c only.

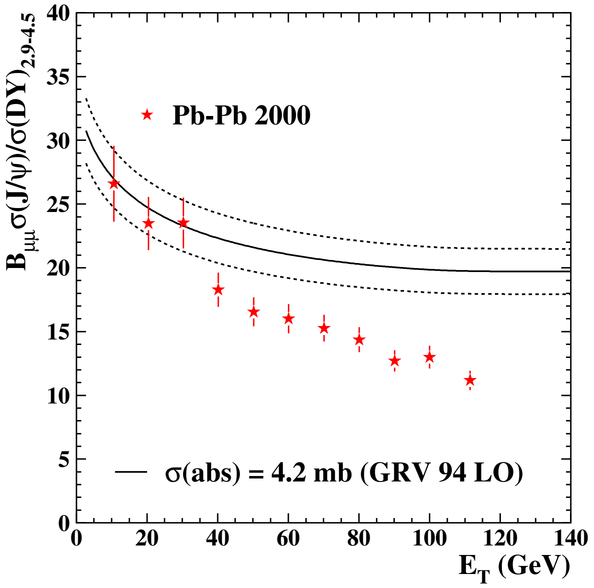

Figure 2. Jψ/DY ratio as a function of the transverse energy, in Pb-Pb collisions. Normal absorption curve extracted from p-A data only.

4. Studies as a function of centrality

Figure 2 shows J/ψ/DY as a function of centrality in Pb-Pb collisions, from the analysis of the 2000 data set, together with the normal absorption curve obtained from proton data only. The normal nuclear absorption curves from each of the methods explained above exactly coincide, the second method being affected by a larger systematical error band (9% as compared to 4% in the more central region), thus showing that the J/ψ suppresssion in S-U collisions is fully compatible with the normal behaviour observed in p-A collisions.

Three independent analyses were performed using the 2000 data set, as a function of the neutral transverse energy, as a function of the energy of the spectator nucleons and as a function of the charged particles multiplicity. All the analyses show a similar J/ψ/DY suppression, that increases with the centrality of the collisions. For the most central collisions, this suppression is much stronger than what one would expect from an extrapolation of the normal nuclear absorption behaviour.

The analyses of 1998 and 2000 data sets are in very good agreement, allowing for the averaging of J/ψ/DY results in each centrality region, thus increasing the statistical precision of the result.

5. $\psi\prime$ suppression

The $\psi\prime$ vector-meson production is more difficult to analyse than the J/ψ, since it has a small dimuon cross-section, and several physics processes superimpose in its invariant mass region. Namely, the estimation of the Drell-Yan contribution under the $\psi\prime$ peak suffers from a 7% uncertainty, depending on the parton distribution functions (PDF) set chosen. Besides, one expects for the $\psi\prime$ a stronger suppression effect as compared to the J/ψ, since this is a less bound charmonium state. In order to minimize the influence of the PDF set chosen in the $\psi\prime$ normalization, the high mass Drell-Yan (4.2 to 7.0 GeV/c^2) is used as reference.

A method of analysis similar to the one used for J/ψ is applied, showing that the $\psi\prime$ is already suppressed in peripheral Pb-Pb collisions, and this effect increases with centrality. Although the statistical error bars are large, there is a very good agreement between the 1998 and the 2000 data analyses. The results were averaged to increase statistical accuracy. The $\psi\prime$ absorption is also shown to be much stronger for Pb-Pb and S-U collisions than for proton induced collisions.

6. Conclusions

The detailed study of the observed J/ψ suppression in Pb-Pb collisions is performed using as reference the Drell-Yan process. This anomalous suppression increases with centrality, departing from the expected normal nuclear absorption deduced from proton induced collisions. The $\psi\prime$ is also shown to be increasingly suppressed with centrality, with the peripheral Pb-Pb collisions producing less resonant events than one would expect from a simple extrapolation of the p-A absorption behaviour.

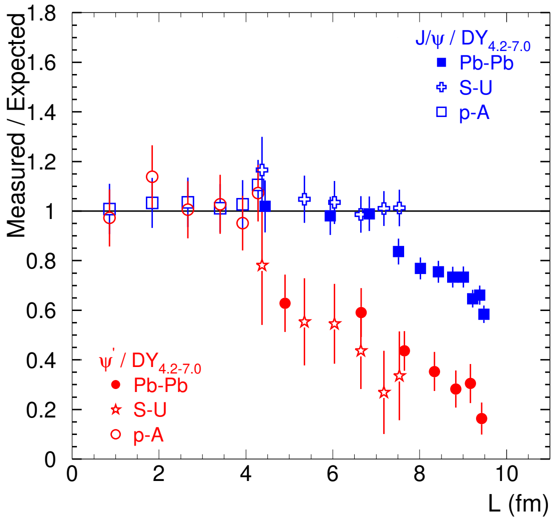

Figure 3. Ratio of J/ψ/DY and $\psi\prime$/DY measured by the corresponding expected values, from normal nuclear absorption (extrapolated from p-A behaviour).

By dividing the measured charmonia/DY ratios by the corresponding expected normal nuclear absorption curves, one can directly compare the J/ψ and $\psi\prime$ suppressions as function of centrality. Figure 3 shows these measured/expected ratios for proton, sulphur and lead induced collisions, showing that in nucleus-nucleus collisions the $\psi\prime$ departs from the normal behaviour earlier than the J/ψ vector-meson.

Acknowledgments

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