SUMMARY OF J/ψ SUPPRESSION DATA AND PRELIMINARY RESULTS ON MULTIPLICITY DISTRIBUTIONS IN PB-PB COLLISIONS FROM THE NA50 EXPERIMENT

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The NA50 fixed target experiment studies the J/ψ and Drell–Yan (DY) production measuring their decay channel into dimuons. The data from Pb-Pb collisions at 158 GeV per nucleon were collected at CERN SPS in the 1995, 1996 and 1998 lead ion runs. The sharp anomalous J/ψ suppression at measured value of the neutral electromagnetic transverse energy (E_T) of about 40 GeV is fully confirmed within the whole data taking period. Moreover a second drop in the J/ψ suppression is seen for the most central collisions. The observed suppression pattern can be considered as a strong indication of the production of a deconfined quark-gluon phase in central Pb-Pb collisions. Here for the first time we present also the preliminary results on the measured charged multiplicity.

1 Introduction

The aim of the NA50 experiment is the study of nuclear matter under extreme energy density conditions, with the ultimate goal of detecting signals of a phase transition from ordinary nuclear matter to a plasma of deconfined quarks and gluons, as predicted by QCD. In particular, the experiment is designed to look for the decays of the charmonium states into dimuons, since the J/ψ suppression was predicted as an unambiguous signature of deconfinement[1]. NA50 follows the program of the NA38 and the NA51 experiments which studied J/ψ production with proton, oxygen and sulphur beams on various targets[2]. They observed smooth J/ψ suppression pattern which is fully consistent with present understanding of the ordinary nuclear absorption. Here we present the summary of the measured J/ψ to DY production cross section ratio over the whole data taking period of the NA50 experiment. The Drell–Yan mechanism is used as a reference for two reasons: first, it simply reflects the number of primary nucleon–nucleon interactions and its behaviour in nucleus–nucleus collisions does not show any evidence for nuclear effects; second, systematic effects concerning the spectrometer cancel out when making ratios like $B_{\mu\mu}(\sigma_{\mathrm{J}/\psi})/\sigma_{DY}$. The results of two different analysis methods are discussed: first, the J/ψ to DY cross section ratio obtained from fits to the muon invariant mass spectrum, which we call hereafter the "standard" method, and second, the ratio obtained evaluating the Drell–Yan events from the Minimum Bias trigger sample. Finally we present the preliminary results on the charged multiplicity distributions for the sample collected during the 1998 lead run.

2 Experimental setup and data taking conditions

The NA50 apparatus[3] consists of a muon spectrometer, detectors measuring the centrality of the nucleus–nucleus collisions and complementary detectors which define the incoming beam, recognize interactions in the target, reject pile–up events etc. A segmented active target (7 subtargets) is used to reject events contaminated by beam fragment reinteractions. Muons are detected with good acceptance in the rapidity interval $2.92 \leq y_{lab} \leq 3.92$ (corresponding to $0 \leq y_{cm} \leq 1$), with a mass resolution of 3.2% at the J/ψ. The event centrality is estimated using three independent detectors: the Pb–scintillating fibers electromagnetic calorimeter EMC ($1.1 \leq \eta_{lab} \leq 2.3$), measuring the neutral transverse energy produced in the interaction; the Tantalium–quartz fibers zero degree calorimeter ZDC ($\eta_{lab} \geq 6.3$), measuring the energy of non–interacting beam fragments, and the 2–plane, high–granularity silicon strip multiplicity detector MD ($1.5 \leq \eta_{lab} \leq 3.5$), measuring the charged particle multiplicity. The setup was very similar for the 1995, 1996 and 1998 ion runs except for the number of subtargets and their thickness. The brief summary of the runs is given in table below.

	1995	1996	1998
Beam Intensity (/burst)	$3 \star 10^7$	$5.4 \star 10^7$	$5.1 \star 10^7$
Target thickness($in\lambda_I$)	17%	30%	7%
Number of triggers	$60 \star 10^6$	$170 \star 10^6$	$80 \star 10^6$
Reconstructed J/ψ events	50000	190000	40000

3 Standard $J/\psi/DY$ analysis

The standard analysis for Drell Yan and charmonium study starts from events triggered by at least two *muon like* tracks in the spectrometer and then an event selection algorithm is applied[4]. The dimuon kinematical domain is defined by $0 \leq y_{cm} \leq 1$ and $-0.5 \leq cos(\theta_{CS}) \leq 0.5$, where the acceptance of the spectrometer is at least 10% of its maximum. The contribution from two muons originating from uncorrelated π and K decays is evaluated with a standard procedure using the two like–sign samples of muon pairs. The mass spectrum above a lower limit of 2.9–3.05 GeV/c^2 is fitted as the superposition of five contributions[4]: J/ψ, ψ', Drell–Yan, open charm semileptonic decays including a charm–like excess in the intermediate mass region [5] and background. The signal-to-background ratio is larger than 10 at the J/ψ peak. The example of invariant mass spectrum for opposite sign dimuons is shown in fig. 1. Usually the final ratio $J/\psi/DY$ is presented as the function of E_T

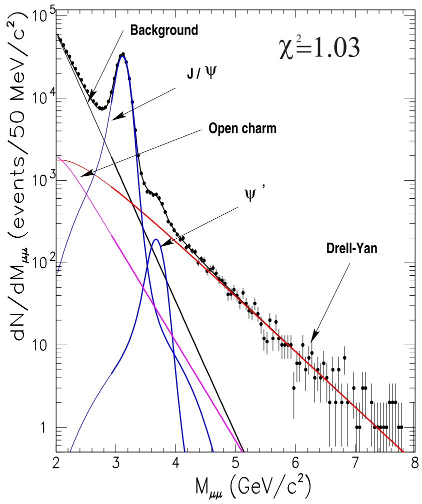

Figure 1. $\mu^+\mu^-$ invariant mass spectrum. 1996 data set.

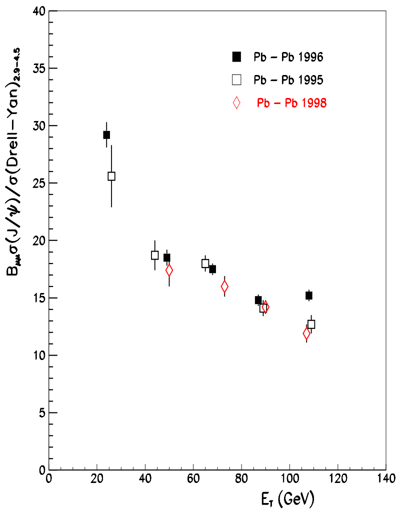

Figure 2. The $J/\psi/DY$ cross section for different runs.

and so the invariant mass spectrum analyses are performed separately for each E_T bin. The 1995 sample is analysed in 5 centrality bins, while the 1996 one is analysed in up to 15 bins, thanks to the higher statistics. For the 1998 run, the present analysis is limited to $E_T > 40$ GeV. Fig. 2 shows the comparison of the measured $J/\psi/DY$ ratio for all lead runs using 1995 run coarse binning. Very good agreement between different runs is seen except the most central point for the 1996 run. Already during the analysis of the 1996 run data it was suspected that the most central point suffered from reinteractions, since a too small fraction of the expected reinteraction events was measured. The most central point of the 1998 data is a clear confirmation that this was the case. In fig. 3 the $J/\psi/DY$ ratio for the 1996 run is shown. It shows clearly the drop of the J/ψ cross section at E_T about 40 GeV. Moreover the anomalous suppression pattern is seen here for the first time within the same data sample since for lower E_T values experimental points agree with ordinary nuclear absorption curve obtained from lighter systems. This agreement is seen better showing the $J/\psi/DY$ ratio as the function of the variable L, which expresses the average length traveled by the produced $c\bar{c}$ state in nuclear matter (fig. 4). Here all the points starting from p-p through p-A

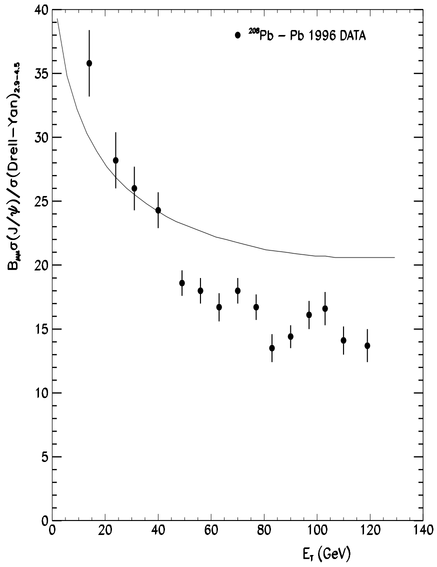

Figure 3. The $J/\psi/DY$ cross section for the 1996 run. Solid curve accounts for the ordinary nuclear absorption with $\sigma_{abs} = 6.4\,mb$.

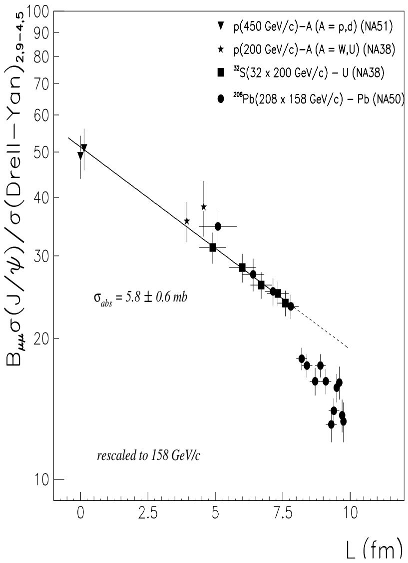

Figure 4. The $J/\psi/DY$ ratio versus L.

up to S–U and peripheral Pb–Pb collisions stay well on the same absorption curve, while the more central Pb–Pb points show a significant drop. The big fluctuations of experimental points come basically from poor statistics of the Drell–Yan events.

4 Minimum bias analysis

In order to reduce statistical errors which limited the accuracy of the standard analysis and to check the results by independent calculations a new method of analysis has been developed[4]. The method does not use the fitting procedure but the numbers of events for the $J/\psi/DY$ ratio are obtained from a simple counting technique. In each E_T bin the number of muon pairs in the mass region 2.9–3.3 GeV is counted which, after combinatorial background subtraction and continuum contribution correction, leads to the number of J/ψ events. The number of Drell-Yan events is estimated from the data sample based on a "minimum bias" (ZDC) trigger in the following way. As a first step the ratio $N_{AB}(E_T)$:

$$\frac{N_{DY}(E_T)}{N_{MB}(E_T)} \sim N_{AB}(E_T)$$

is calculated in the framework of the Glauber model. Then the number of experimental Drell–Yan ($N_{DY^\star}(E_T)$) events is estimated from:

$$N_{DY^\star}(E_T) = N_{MB}^{exp}(E_T) \times N_{AB}(E_T)$$

The normalization of the new $J/\psi/DY$ ratio is done by fixing the new curve to the standard analysis one in the flattest part ($55GeV < E_T < 75GeV$).

This new approach has several important advantages. Since the estimation is done from the very high statistics set of minimum bias events, the statistical errors become negligible. For the same reason it is possible to use only the sample of events identified by target algorithm without the increase of statistical errors. No fits to the mass spectra are done in this type of analysis and so a possible systematic error coming from fitting procedures is eliminated. With this method some new systematic effects are possible: using a different type of trigger (ZDC), no quality cuts based on the muon tracks can be applied for the determination of $N_{DY^\star}(E_T)$. The possible contamination from the Pb–air collisions is crucial for the most peripheral events. For this reason in the present analysis only the events with $E_T > 26$ GeV are used. The comparison between the results obtained with the standard method and the minimum bias method is shown in fig. 5 for the 1996 data set. The anomalous drop of J/ψ cross section about 40 GeV is in excellent agreement with the standard method. As one would expect big statistical fluctuations between the points obtained with the standard method disappear when using the minimum bias method, which profits from much bigger sample of minimum bias events. For the same reason finer E_T binning is applied. With improved binning the reinteraction problem for the central events of the 1996 data set is well visible when comparing this data to the 1998 data sets (fig. 6). Moreover it is also seen that for the most central collisions ($E_T > 90GeV$) a second drop in J/ψ cross section appears. The full suppression pattern is shown in fig. 7 where the results of 1996 and 1998 runs are put together, after cutting the biased most central part of the 1996 data.

5 Charged Multiplicity distributions

A small sample of the 1998 data (40000 events) collected by the Multiplicity Detector was analyzed in order to obtain the charged multiplicity distributions. The data were divided into 6 different centrality bands as a function of

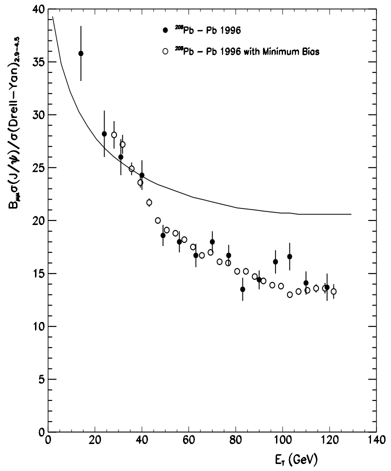

Figure 5. $J\psi/DY$ ratios from standard and minimum bias analyses for 1996 data set

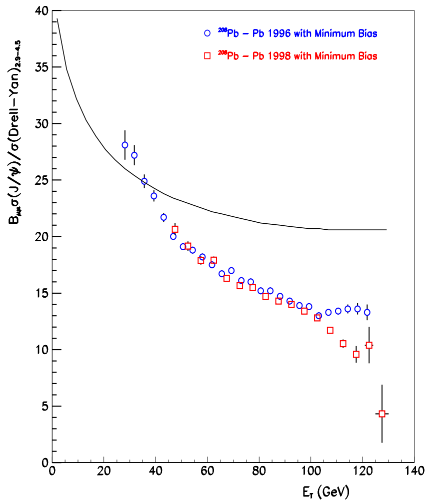

Figure 6. The 1996 and the 1998 $J/\psi/DY$ ratios from minimum bias analyses

the forward energy (E_{ZDC}) measured by the zero degree calorimeter. Hardware corrections were applied for the energy loss in the silicon detector (Landau distributions), for the inefficiency caused by trigger delay jitter between the trigger of the experiment and multiplicity detector trigger, for the multiple strip occupancy and for the crosstalk between detector channels. Delta electrons were subtracted by means of GEANT simulations and corrections for gamma conversions and secondary interactions were applied on the basis of GEANT+VENUS simulations. Distributions of the hits in the detectors were used to fix preliminarly the detector position. The uncertainty of the detector aligment and the method applied to correct for the cross talk effect may result in systematic error up to 25%. In fig. 8 the preliminary pseudorapidity distributions for different centrality bands are plotted. The error bars account for the statistical errors only.

6 Conclusions

The $J/\psi/DY$ ratios obtained for different runs and analysed with standard and minimum bias methods are internally consistent. They show two anomalous drops in J/ψ cross section with increasing centrality of the collision (E_T),

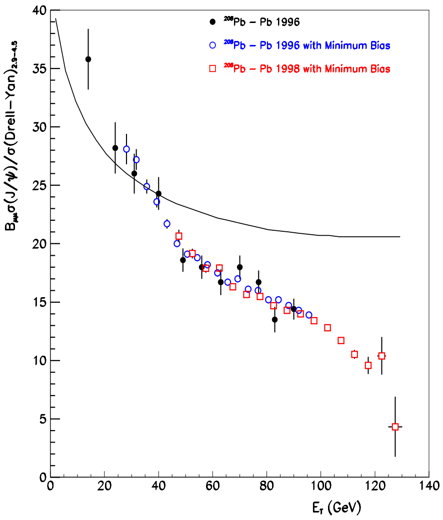

Figure 7. Final, combined $J\psi/DY$ suppression pattern

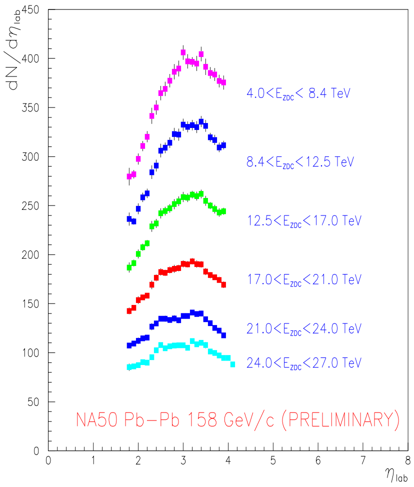

Figure 8. Pseudorapidity distributions of the N_{ch} in six centrality bands.

the first one at about 40 GeV and the second one above 90 GeV. The observed suppression pattern rules out all conventional hadronic scenarioes which always predict a smooth suppression behaviour. Preliminary pseudorapidity distributions measured by the NA50 experiment are shown.

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