THE ONSET OF THE ANOMALOUS J/Ψ SUPPRESSION IN Pb-Pb COLLISIONS AT THE CERN SPS

R. ARNALDI - NA50 collaboration

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The J/ψ suppression observed by the NA50 experiment is one of the most striking signatures for quark gluon plasma formation in Pb-Pb collisions at 158 AGeV. The J/ψ production has been studied as a function of the centrality of the collision estimated via the forward energy E_{ZDC} released in a zero degree calorimeter (ZDC). The study of the correlation between the number of participant nucleons in the collisions, N_{part}, and E_{ZDC} allows to check whether the J/ψ suppression pattern vs. E_{ZDC} is compatible with a sudden J/ψ suppression mechanism expressed as a function of N_{part}.

1 Introduction

If extreme conditions of high energy density and temperature are reached, a phase transition between hadronic matter and a state of deconfined quarks and gluons (QGP) should be achieved.

Experimentally, the best tool to study the formation of the QGP is provided by ultrarelativistic heavy ion collisions and several probes have been investigated as signatures of the phase transition. One of the most striking signals is the J/ψ suppression, as proposed by Matsui and Satz in 1986 [1]. In fact, QGP formation induces a colour screening of the charmonium binding potential, preventing the c and $\bar{c}$ quarks to form charmonia bound states; hence a reduction of the J/ψ production yield, the so-called J/ψ suppression, is expected.

The NA38 experiment studied the J/ψ production with p and S induced reactions [2,3,4].

In such collisions, even if the required conditions for the phase transition were not achieved, a reduction of the J/ψ production yield was already observed. Such a "suppression" has been interpreted as due to nuclear absorption of the $c\bar{c}$ pair, before it forms a J/ψ, and it can be used as a baseline for the interpretation of the results obtained by the NA50 experiment in Pb-Pb collisions.

NA50 has already published data on J/ψ production as a function of the centrality estimator E_T [8,9], i.e. the neutral transverse energy. The result indicates an additional J/ψ suppression mechanism (the "anomalous J/ψ suppression"), not present in S–U interactions. The observed J/ψ suppression pattern from peripheral to central collisions shows a two-step behaviour, possibly linked with the successive melting in a deconfined state of the χ_c which, through its radiative decay, is an important J/ψ source, and of the strongly bound J/ψ itself. A similar analysis performed as a function of another centrality estimator, E_{ZDC}, is presented in this talk.

2 The experimental apparatus and data taking conditions

A detailed description of the NA50 apparatus can be found in [5,6,7]. The main component of the set-up is a dimuon spectrometer covering the pseudorapidity range $2.8 < \eta < 4.0$. Furthermore, NA50 is equipped with three centrality detectors: an electromagnetic calorimeter, measuring the neutral transverse energy E_T, a silicon microstrip detector, which allows to estimate the charged multiplicity and a zero degree calorimeter (ZDC). The ZDC, which covers the pseudorapidity region $\eta \geq 6.3$, is placed on the beam line, measuring the forward energy E_{ZDC}, mainly carried by projectile nucleons which have not taken part in the collision.

The results discussed here refer to the 1996 and 1998 data taking periods. The differences between the two set-ups concern only the target region. In 1996, 7 sub-targets were used, with a total thickness corresponding to 30% λ_I, while in 1998 only one single thin target (7 % λ_I) was used.

Data have been collected with two different triggers: the "dimuon trigger" and the "minimum bias" one. The first one corresponds to events where the spectrometer detects a couple of muons produced in the target region, while the second one fires every time a small amount of energy is released in the ZDC. Information on data taking conditions and event selection can be found in [8,9].

3 E_{ZDC} and the centrality of the collision

The geometry of the collision is usually characterized by the impact parameter b. This variable is not directly measured, but it is accessible via measurements of other quantities, like the zero degree energy E_{ZDC}. In fact, since the ZDC is placed on the beam line, it intercepts all the nucleons which have not taken part in the collisions (i.e. spectator nucleons N_{spect}) and which fly towards the detector, with the beam energy. Hence the measured zero degree energy is directly proportional to the number of spectator nucleons impinging on the detector and therefore to the impact parameter b.

For a generic Pb–Pb collision, the average $< E_{ZDC} >$ is given by the sum of two terms: a dominant one which refers to the contributions of the spectator nucleons, plus a smaller contribution proportional to the number of participant nucleons N_{part} emitted in the calorimeter acceptance. The link between N_{part} (or N_{spec}) and b has been obtained with a calculation based on a Glauber model of nucleus–nucleus collisions, using Woods-Saxon nuclear density profiles.

For a generic b the E_{ZDC} values are gaussian distributed around $< E_{ZDC} >$ with a width $\sigma_{E_{ZDC}}$ which takes into account both the finite resolution of the detector and the size of the physics fluctuations due to the width of the correlation between b and N_{part}.

4 Study of the J/ψ suppression

The J/ψ suppression pattern as a function of E_{ZDC} has been obtained with the "minimum bias" analysis. The explanation of this technique can be found in [8,9]. Basically the number of J/ψ events, obtained from the $\mu^+\mu^-$ invariant mass spectrum, is divided by a "calculated Drell–Yan (DY^*)", estimated from the minimum bias sample of events. The result is shown in Fig. 1a, where the continuous line refers to the baseline established by the data collected with lighter projectiles. Since 1996 and 1998 set-ups were respectively optimized for the study of peripheral and central collision, the results are presented for the corresponding range of centralities. In

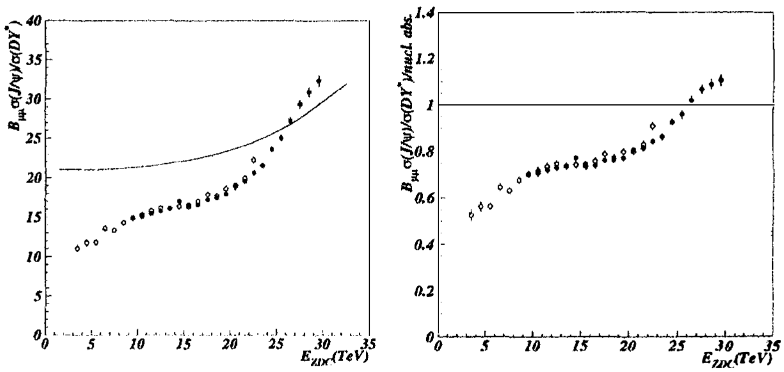

Figure 1: (a) J/ψ suppression as a function of E_{ZDC}. Full symbols refer to 1996 data and open symbols to 1998 data. The continuous line represents the J/ψ suppression due to ordinary nuclear absorption; (b) the $J/\psi/DY^*$ ratio divided by the absorption curve, as a function of E_{ZDC}

Fig. 1b, the $J/\psi/DY^*$ result is divided by the nuclear absorption curve.

We observe a departure from the expected standard behaviour around $E_{ZDC} \sim 27$ TeV, while a second steep decrease is visible in the region corresponding to the most central collisions. A suppression pattern with the same characteristics has been obtained with the analysis performed as a function of E_T [8,9].

5 J/ψ suppression versus N_{part}

The variable governing the onset of the anomalous suppression is a priori not known. Hence, exploiting the link between E_{ZDC} and N_{part}, we check if the suppression pattern of Fig. 1b is compatible with two sharp drops in the J/ψ yield occurring at definite values of N_{part}. In the interpretation of Ref. [9] the two steps should correspond to the melting, in a deconfined state, of the χ_c with suppression of the J/ψ from the decay $\chi_c \rightarrow J/\psi\gamma$ at N_{part}=N_1, followed by the suppression of directly produced J/ψ at N_{part}=N_2. Taking into account the N_{part} versus E_{ZDC} correlation, and the finite resolution on N_{part} due to the detector response, we calculate the theoretical $(J/\psi/DY^*)$/Absorption ratio vs E_{ZDC}.

The agreement between the experimental data and this naive model is shown in Fig. 2; the experimental points result to be well described with N_1=122, N_2=334.

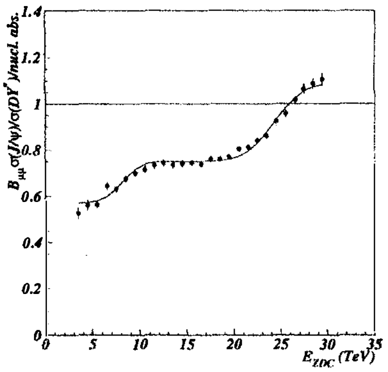

Figure 2: The fit of $J/\psi/DY^*$ vs E_{ZDC}, assuming two sharp absorption mechanisms of free amplitude occurring at N_1=122 and N_2=334.

However, a more detailed study [10] shows that data could accomodate equally well an onset of the suppression smeared over a certain limited N_{part} range, not larger than 25 N_{part}.

6 Conclusions

The J/ψ suppression pattern as a function of E_{ZDC} has been presented. The double step pattern, already observed in a similar analysis as a function of E_T and interpreted as an evidence for deconfinement at SPS energy [9], is found again in this analysis.

Using the relation between E_{ZDC} and N_{part} the suppression pattern can be plotted as a function of N_{part}. Taking into account the finite resolution on N_{part} induced by the experimental resolution on E_{ZDC}, it turns out that the onset of the anomalous J/ψ suppression occurs in a very limited N_{part} range, smaller than 25 participant nucleons.

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