TRANSVERSE MOMENTUM OF DIMUONS PRODUCED IN p-Cu, p-U, ^{16}O-Cu, ^{16}O-U and ^{32}S-U COLLISIONS AT 200 GeV PER NUCLEON

NA38 Collaboration

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Abstract : The NA38 experiment measured the muon pair production in interactions of p and ^{16}O with Cu and U and in ^{32}S-U collisions at 200 GeV per nucleon incident energy. The transverse momentum distribution of the J/ψ and of muon pairs in the mass continuum ($1.7 < M_{\mu\mu} < 2.7$ GeV/c^2) has been studied, taking into account the acceptance and smearing effects of the apparatus. For the J/ψ, the average values of the transverse momentum $<P_T>$ and $<P_T{}^2>$ show a clear increase with the energy density reached in ^{16}O and ^{32}S induced reactions, which is not observed for muon pairs in the mass continuum. Such a behaviour is in agreement with quark-gluon plasma models. However, models based on parton multiple scattering in the initial state are also able to reproduce the data.

The NA38 collaboration measured the dimuon production in p-Cu, p-U, ^{16}O-Cu, ^{16}O-U and ^{32}S-U reactions at 200 GeV per nucleon, in correlation with the neutral transverse energy E_T^0 produced in the interaction, which reflects the centrality of the collision. It has been observed[1] that the J/ψ yield relative to the dimuons in the mass continuum decreases with increasing E_T^0. In addition[2], this effect was found to be enhanced at low transverse momentum P_T. Such a behaviour is in agreement with the predictions of quark-gluon plasma (QGP) models[3] in which the colour screening effect prevents the binding of the $c-\bar{c}$ pair, depending on its transverse momentum[4]. It is therefore important to study the P_T dependence of J/ψ production as a function of E_T^0.

Measurements were performed at the CERN SPS, using the highest available intensity (up to 10^7 ions/s). The spectrometer detected muon pairs in the lab rapidity range $2.8 < y < 4.1$, in correlation with E_T^0, the neutral transverse energy deduced from the energy flow measured by an electromagnetic calorimeter in the pseudorapidity range $1.7 < \eta_{lab} < 4.1$. More details on the experimental set-up and event selection criteria can be found elsewhere[1,2].

Only dimuons with invariant mass $M_{\mu\mu} \geq 1.7$ GeV/c^2 are considered here. In this mass region, the signal in the opposite sign (OS) dimuon spectra originates mainly from J/ψ and ψ' meson decays, semi-leptonic decays of $D\bar{D}$ pairs, and from the Drell-Yan mechanism. For each kinematical variable, the number N_{Bk}^{+-} of background pairs coming from pion and kaon decays is estimated from the like sign (LS) pair spectra, using the formula :

$$N_{Bk}^{+-} = 2\sqrt{N^{++}N^{--}}$$

where N^{++} (N^{--}) is the number of $\mu^+\mu^+$ ($\mu^-\mu^-$) pairs in the corresponding distribution. In the following, J/ψ's are defined as events with mass between 2.7 and 3.5 GeV/c^2, and continuum dimuons as events outside this mass interval.

In order to study the transverse momentum distributions of J/ψ's and continuum dimuons, the acceptance and smearing effects of the apparatus are taken into account. This treatment is performed by the means of transfert matrices obtained from the simulation of the NA38 detector[2]. The P_T distributions of the OS muon pairs are parametrized according to :

$$P_T \; e^{-\left(\frac{P_T}{P_{T0}}\right)^{\beta}}$$

A fit through the acceptance and smearing matrices, taking into account the background contribution in the OS spectra, leads to the parameters P_{T0} and β of this phenomenological P_T distribution for J/ψ's and for muon pairs in the mass continuum. The average values $<P_T>$ and $<{P_T}^2>$ deduced from the resulting distributions are gathered in table 1 for proton and ion induced reactions. As one can see from these results, for the J/ψ, the values obtained for proton induced reactions are not compatible with those corresponding to ion-uranium collisions.

In order to investigate this effect as a function of the centrality, the same procedure is applied for different E_T^0 intervals. For proton-copper and proton-uranium collisions, no analysis as a function of E_T^0 is performed, as E_T^0 and impact parameter are in this case loosely correlated. For each E_T^0 bin, the energy density reached in the collisions is estimated using the Bjorken formula :

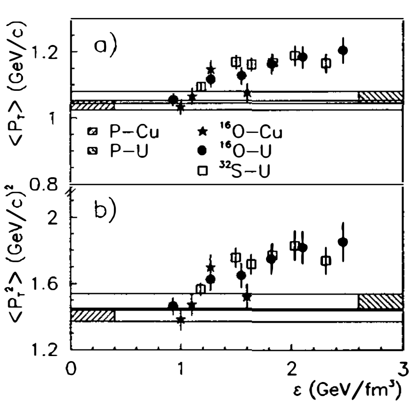
$$\varepsilon = \frac{3 < E_T^0 >}{\Delta\eta \; \tau_0 \; \bar{S}}$$

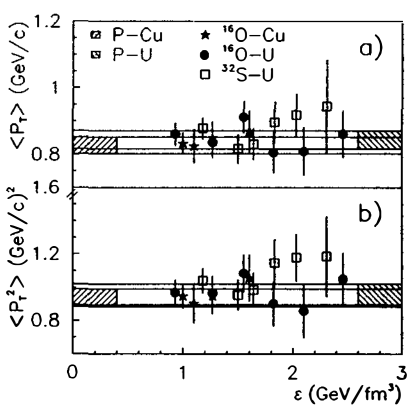
where $< E_T^0 >$ is the mean neutral transverse energy measured in the pseudorapidity range $\Delta\eta$, and $\bar{S}$ is the mean overlap area of the colliding nuclei at the time τ_0=1fm/c.

	Continuum		J/ψ	
all E_T^0	$< P_T >$	$< P_T^2 >$	$< P_T >$	$< P_T^2 >$
p-Cu	0.83 ± 0.03	0.94 ± 0.05	1.04 ± 0.02	1.41 ± 0.04
p-U	0.84 ± 0.03	0.96 ± 0.06	1.06 ± 0.02	1.49 ± 0.05
^{16}O-Cu	0.84 ± 0.03	0.94 ± 0.06	1.08 ± 0.01	1.52 ± 0.04
^{16}O-U	0.85 ± 0.02	0.98 ± 0.05	1.12 ± 0.01	1.64 ± 0.03
^{32}S-U	0.87 ± 0.02	1.06 ± 0.05	1.14 ± 0.01	1.69 ± 0.03

Table 1 : *Values of $<P_T>$ and $<P_T{}^2>$ obtained after correction for acceptance and smearing, for J/ψ's and for muon pairs in the mass continuum.*

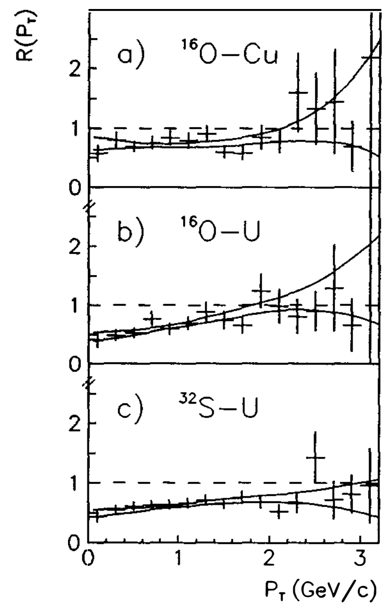
The values of $<P_T>$ and $<P_T{}^2>$ as a function of ε are plotted in figure 1 for the J/ψ, and in figure 2 for continuum events. As shown in figure 1, for the J/ψ, $<P_T>$ and $<P_T{}^2>$ display a clear increase with ε. Such a behaviour is not seen in the case of continuum dimuons, for which the values of $<P_T>$ and $<P_T{}^2>$ obtained in ion-nucleus collisions are, within statsitics, compatible with those measured in p-Cu and p-U reactions.





Figures 1 and 2 : *Values of $<P_T>$ (a) and $<P_T{}^2>$ (b) as a function of the energy density ε, for the J/ψ (1) and for events in the mass continuum (2).*

To study the transverse momentum dependence of the J/ψ suppression, the ratio $R(P_T)$ of the transverse momentum distributions corresponding to the two extreme E_T^0 bins is calculated. Each distribution is normalized to the number of continuum events in the J/ψ mass range, in the corresponding E_T^0 interval :



$$R(P_T) = \frac{\left(\frac{1}{N_C}\frac{dN^{\psi}}{dP_T}\right)_{HighE_T^0}}{\left(\frac{1}{N_C}\frac{dN^{\psi}}{dP_T}\right)_{LowE_T^0}}$$

This ratio is shown in figure 3 as a function of P_T. One can see that R increases with P_T, indicating that the J/ψ suppression is enhanced for low transverse momentum values. Such an increase is expected from quark-gluon plasma models, which predict, in addition, a saturation of R with P_T. However, other interpretations[5], based on parton multiple scattering in the initial state, and J/ψ absorption in a dense hadron gas, are also able to account for the data. In these models, the multiple scattering in the entrance channel allows the incident partons to acquire transverse momentum, leading, for the J/ψ, to a value of $<P_T{}^2>$ which increases with the centrality of the collision. In this frame, $R(P_T)$ should not saturate with P_T. Unfortunately, the available statistics do not permit to distinguish between both models.

Figure 3 : *$R(P_T)$ for ^{16}O-Cu, ^{16}O-U and ^{32}S-U collisions, deduced from the fitted P_T distributions (solid lines), and calculated directly from the data (error bars).*

Another analytical form of the J/ψ P_T distribution, using the transverse mass parametrization :

$$P_T\; e^{-\frac{\sqrt{P_T^2+M_\psi^2}}{T}}$$

leads to the values of the parameter T, presented in figure 4. The ε dependence of this parameter, usually considered as a temperature in thermal models, has been fitted according to $T = a\,\varepsilon^{1/b}$. With T expressed in GeV, the results of the fit (represented by the solid line in figure 4) are : $a = 0.212 \pm 0.002$ and $b = 3.9 \pm 0.4$

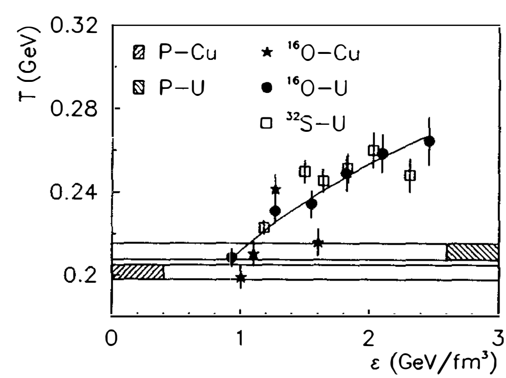


Figure 4 : *Values of the parameter T, as a function of the energy density ε*

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