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Low Mass Vector-Meson Production in p-W and S-U High Energy Collisions

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Abstract

NA38 results on $\rho + \omega$ and ϕ production in p-W and S-U interactions at 200 GeV/nucleon are presented. Transverse mass distributions and slopes are measured. The value of the ratio $\frac{B_\phi \sigma_\phi}{B_\rho \sigma_\rho + B_\omega \sigma_\omega}$ is given for different P_T regions as a function of ϵ. It is found that this ratio is independent of P_T and that it increases with ϵ when going from p-W to S-U collisions. Assuming the A dependence $\sigma_{SU} = \sigma_0 (A_{beam} \cdot A_{target})^\alpha$, we obtain α_ϕ values significantly bigger than one and greater than the $\alpha_{\rho+\omega}$ values in different P_T regions. All these results clearly show a ϕ enhancement going from $p - W$ to $S - U$ interactions independent of P_T.

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Presented by Paula Bordalo[4b]

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NA38 results on $\rho + \omega$ and ϕ production in p-W and S-U interactions at 200 GeV/nucleon are presented. Transverse mass distributions and slopes are measured. The value of the ratio $\frac{B_\phi \sigma_\phi}{B_\rho \sigma_\rho + B_\omega \sigma_\omega}$ is given for different P_T regions as a function of ϵ. It is found that this ratio is independent of P_T and that it increases with ϵ when going from p-W to S-U collisions. Assuming the A dependence $\sigma_{SU} = \sigma_0(A_{beam} \cdot A_{target})^\alpha$, we obtain α_ϕ values significantly bigger than one and greater than the $\alpha_{\rho+\omega}$ values in different P_T regions. All these results clearly show a ϕ enhancement going from $p-W$ to $S-U$ interactions independent of P_T.

INTRODUCTION

In the framework of Quark-Gluon Plasma (QGP) formation, it is expected that at sufficientely high energy densities a chemical equilibrium be reached (1), and that strangeness abundances increase . Also, A.Shor (2) predicted a $\frac{\phi}{\omega}$ ratio enhancement in heavy ion collisions as compared to pp interactions, in which the ϕ production is suppressed by the OZI rule (3).

Since 1989, NA38 experiment has been showing results on the $\frac{\phi}{\rho+\omega}$ ratio production in the dimuon channel, and at that time it was found an enhancement at high dimuon transverse momentum (P_T) in nucleus-nucleus interactions with increasing energy density and as compared to proton collisions (4). Two years later, NA38 measured the ϕ and $\rho+\omega$ cross section productions either at low and high P_T domains; again the ratio enhancement was observed and it was shown not to be a P_T effect (5,6), on the contrary to what was argued (7).

It was also pointed out by our collaboration that this $\frac{\phi}{\rho+\omega}$ ratio increase is due to the ϕ enhancement and not a $\rho+\omega$ system absorption, using these resonance cross section's measurements in p-W and S-U collisions and their A dependence (5,6).

In this paper, we present ϕ and $\rho+\omega$ transverse mass (M_T) cross section measurements and their slopes (the so-called temperature T). Preliminary results concerning the inclusion of a new data sample in our $\frac{\phi}{\rho+\omega}$ analysis as a function of energy density (ϵ) and P_T are shown. Also, the value α in the $(A_{beam} \cdot A_{target})^{\alpha}$ dependence is calculated as a P_T function for the resonances ϕ and $\rho+\omega$.

EXPERIMENT AND DATA ANALYSIS

The present analysis concerns to p-W and two special periods of S-U collisions at 200 GeV/nucleon with dedicated configurations of the NA38 spectrometer in order to improve mass resolution and to reduce background level due to π and K decays. Both setups are designed in a compact way based on light materials (C, BeO for p-W, and C, Al_2O_3 for S-U). In S-U collisons, we also used an electromagnetic calorimeter made of Pb/Sc fibre (2:1 volume ratio) in the rapidity range outside of the dimuon acceptance. At the ϕ mass, the mass resolution is 8% (9%) in p-W (S-U) interactions, and the background to signal ratio varies from 0.8 to 2.0 (0.07 to 0.15) under the resonances in sulphur (proton) runs (Fig. 1). More details on the layout configurations can be found elsewhere (6,8).

This analysis is done in the kinematical domains $P_{T\mu\mu} \geq 0.6$ GeV/c and $3.0 \leq y_{\mu\mu} \leq 4.0$, which ensures an acceptance greater than 1% in the dimuon mass and transverse momentum regions considered (see Fig. 2), and the same decay path for all mesons. The signal dimuon distributions are obtained after

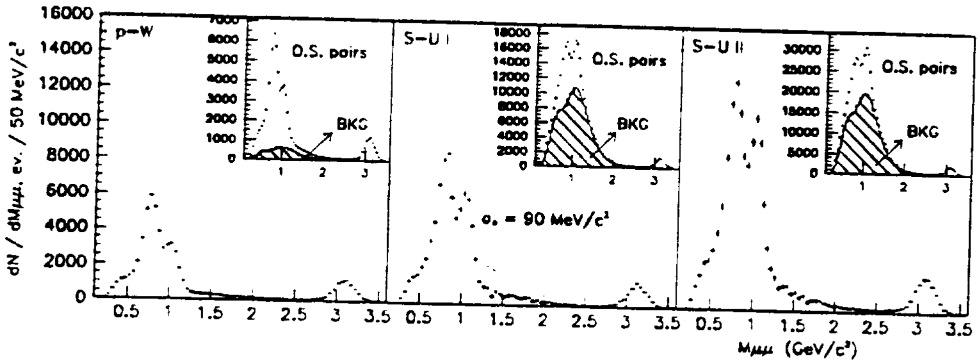

FIG. 1. Dimuon mass distributions for the $p-W$ sample and two $S-U$ data phases, I and II, at 200 GeV/nucleon. Inserts show opposite sign and background distributions. σ_ϕ is the the ϕ mass resolution.

a multidimensional background subtraction procedure in M, P_T, E_T^0 (M, P_T) for $S-U$ $(p-W)$ data, as described hereafter. The combinatorial background originating from uncorrelated decays of pions and kaons is determined from like-sign muon pair samples $N^{\mu^+\mu^+}$ and $N^{\mu^-\mu^-}$ in each magnetic field sign, according to

$$N_{bg}^{+-} = 2\,R\,(\sqrt{N_+^{\mu^+\mu^+}N_+^{\mu^-\mu^-}} + \sqrt{N_-^{\mu^+\mu^+}N_-^{\mu^-\mu^-}}\,)\ . \tag{1}$$

We garantee the same acceptance for both muon signs by applying a geometrical cut which insures the validity of this formula. The factor R depends on the meson multiplicity distributions. We have measured the value $R = 1.25 \pm 0.04$ for p-W data using two different configurations in what concerns their absorbers. This value is in agreement with what is expected from a Monte Carlo simulation of the background in the NA38 detector, based on the Fritiof event generator (9). In sulphur induced reactions we used $R = 1.00 \pm 0.05$. This value is obtained with the same simulator with a E_T^0 cut ($E_T^0 > 15$ GeV).

A Monte Carlo simulator which reproduces well the experimental M, P_T, and y distributions, after an iterative procedure, is used to correct data for acceptance and smearing. Our acceptance curves are displayed in Fig. 2 and, due to small acceptance values for $P_T^{\mu\mu} < 0.6$ GeV/c, this region is not used in the analysis. A five parameter fit is then performed to the physical distributions:

$$\frac{d^2N}{dM\,dP_T} = a_\rho BW_\rho + a_\omega BW_\omega + a_\phi BW_\phi + a_C e^{-bM}\quad , \tag{2}$$

being $BW_{\rho,\omega,\phi}$ the resonance's Breit-Wigner distributions with masses and widths given by their nominal values. The exponential term accounts for the continuum contribution - Dalitz decays ($\eta \rightarrow \mu\mu\gamma$, $\eta' \rightarrow \mu\mu\gamma$, $\omega \rightarrow \mu\mu\pi^0$),

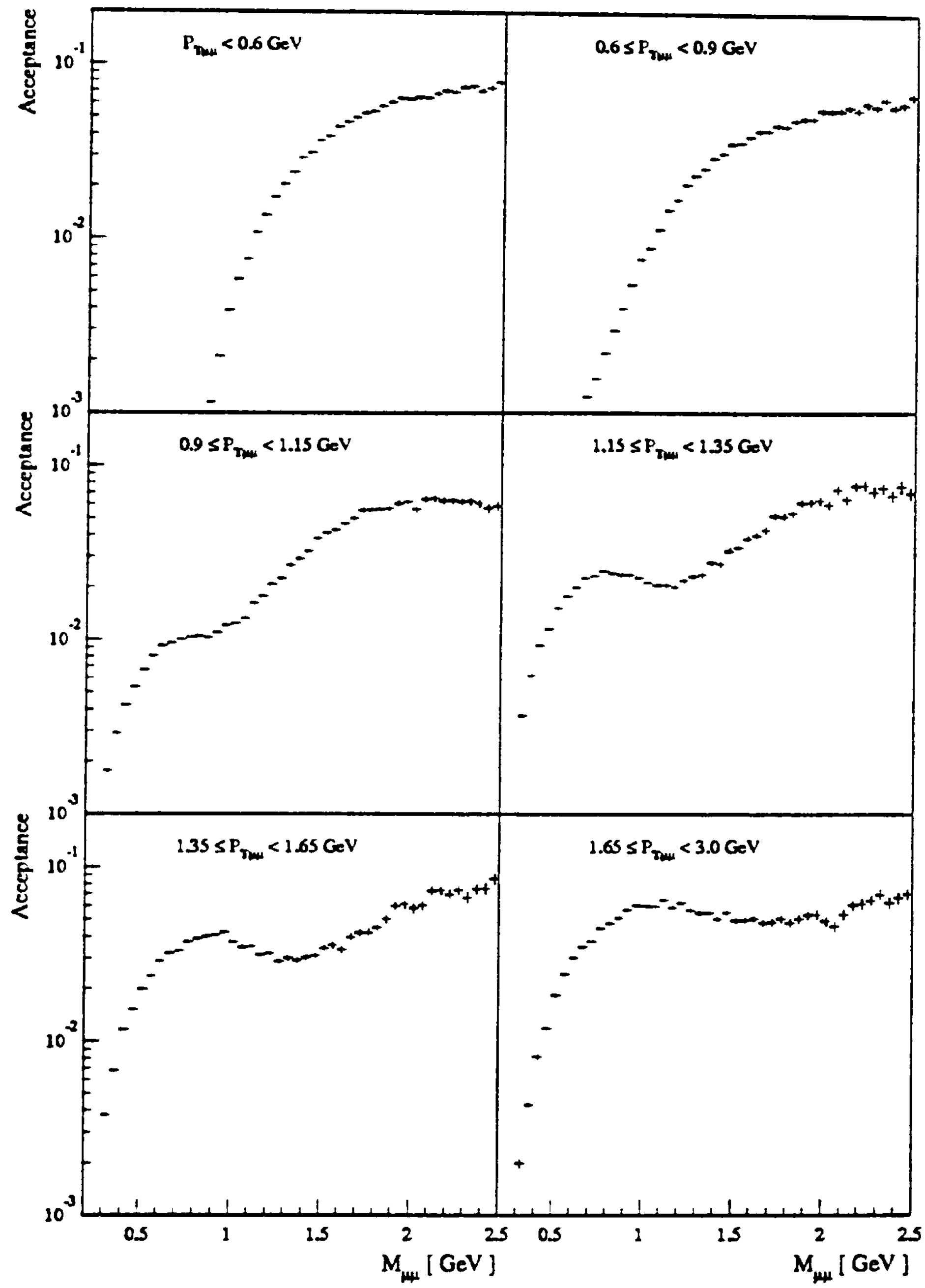

FIG. 2. Dimuon acceptance as a function of mass for 6 dimuon P_T intervals.

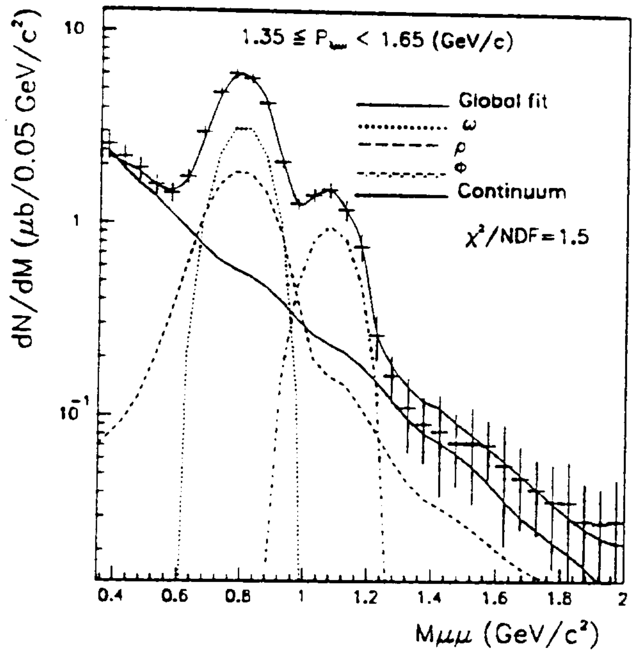

FIG. 3. Typical fit to the dimuon mass spectrum measured in $p-W$ collisions.

semileptonic decays of $D, \bar{D}$ charmed mesons, and Drell-Yan production. A typical fit is shown in Fig. 3 .

In the case of S-U collisions, data is analysed in four E_T bins. For each bin, the corresponding energy density is calculated using the Bjorken formula:

$$\epsilon = \frac{3 \cdot E_T^0}{\tau \cdot \Delta y \cdot S} \quad , \tag{3}$$

with S, the transverse area, computed by a geometrical model (10), Δy the rapidity interval covered by the calorimeter and τ_0 the formation time (1 fm/c).

STUDY OF $\rho+\omega$ AND ϕ PRODUCTION

Transverse mass differential cross sections

Fig. 4 shows our results of $\rho + \omega$ and ϕ transverse mass differential cross sections in p-W and S-U phase I data. The parametrization displayed is the one pointed out by R.Hagedorn (11) for the thermal radiation, in the limit where the mass of the resonance m_R is much greater than temperature ($m_R \gg T$):

$$\frac{1}{{M_T}^{3/2}} \cdot \frac{dN}{dM_T} = A \cdot exp(-\frac{M_T}{T}) \quad . \tag{4}$$

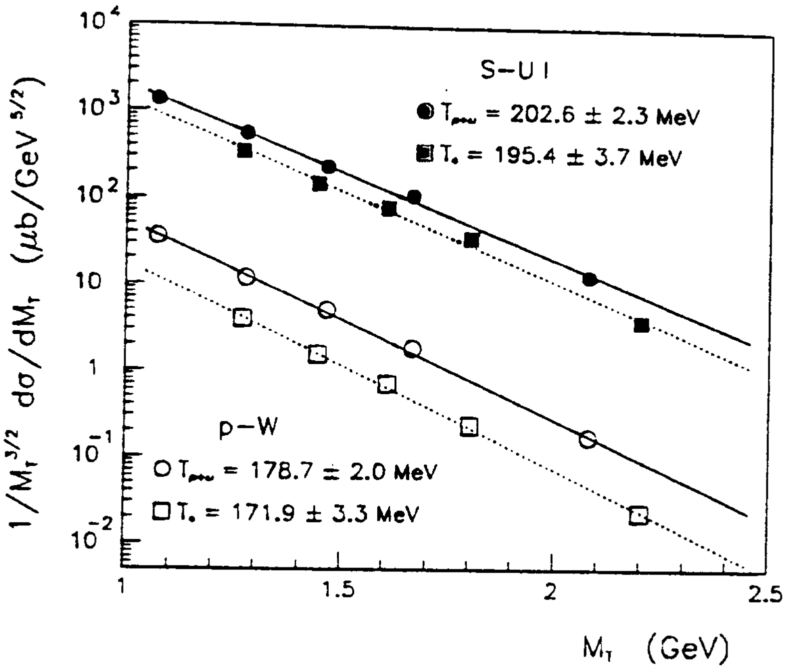

FIG. 4. $(1/M_T^{3/2})\, d\sigma/dM_T|_{\Delta Y}$ $(\mu b/(GeV/c)^{5/2})$, measured in $p-W$ and $S-UI$ collisions at 200 GeV/n. A fit using parametrization (4) is presented and T inverse slope values are extracted.

As we are in the case of the considered limit, this parametrization gives the same results as the original Hagedorn formula:

$$\frac{1}{M_T} \cdot \frac{dN}{dM_T} = A \cdot M_T \cdot K_1(\frac{M_T}{T}) \quad , \tag{5}$$

K_1 being the modified Bessel function.

We observe that the inverse slope T, the so-called temperature, is about 8% higher in S-U interactions as compared to p-W collisions. This can be interpreted as a possible evidence for higher energy densities in S-U reactions. We have checked that this result is not dependent on the parametrization choice. Indeed, when we use the approximation:

$$\frac{1}{M_T} \cdot \frac{dN}{dM_T} = A \cdot exp(-\frac{M_T}{T}) \tag{6}$$

to fit the data, all $T_{\rho+\omega,\phi}$ are globally shifted by about 5% in both reactions.

A study of the vector-meson temperatures as a function of the energy density in S-U I interactions is shown Fig. 5. No ϵ dependence is clearly seen; to

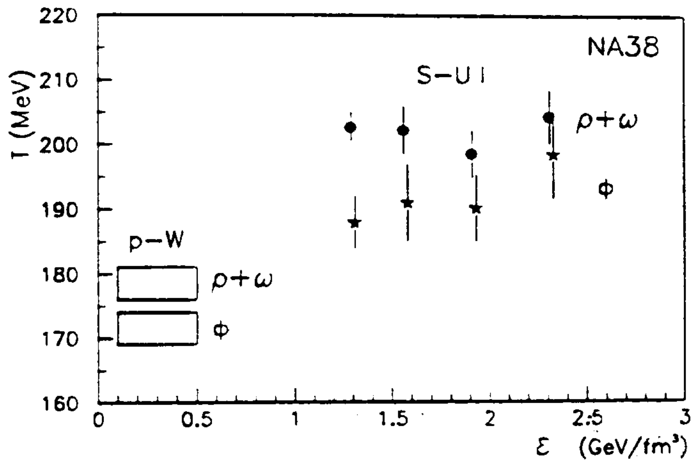

FIG. 5. Temperature T (MeV) of $\rho+\omega$ and ϕ resonances as a function of the energy density ϵ obtained in $S-U$ collisions. The boxes are the temperatures measured in $p-W$. The values presented are obtained by fitting the data with parametrization (4).

get more significant results, the analysis of S-U II data is under way. However, we observe a slight difference between $T_{\rho+\omega}$ and T_ϕ of about 3 to 7% in both reactions.

The cross section ratio $\frac{B_\phi\sigma_\phi}{B_\rho\sigma_\rho+B_\omega\sigma_\omega}$

We measure the $\rho+\omega$ and ϕ cross section production in the dimuon channel as a function of ϵ, for several P_T intervals. Using all data available, that is phases I and II, we extract the ratio values for two P_T regions, one low and another high ($0.6\leq P_{T\mu\mu}\leq 1.15$ GeV/c and $1.15\leq P_{T\mu\mu}\leq 3.0$ GeV/c). The results are displayed in Fig. 6, and we observe, in both domains, a clear increase of the ratio when ϵ is increasing. An enhancement going from p-W to S-U collisions is also seen.

Due to our big statistics we are able to measure the ratio $\frac{B_\phi\sigma_\phi}{B_\rho\sigma_\rho+B_\omega\sigma_\omega}$ for other P_T bins. In Fig. 7 we show the values for bins $1.15\leq P_{T\mu\mu}<1.35$ GeV/c, $1.35\leq P_{T\mu\mu}<1.65$ GeV/c and $1.65\leq P_{T\mu\mu}<3.0$ GeV/c. Still, an increase of the ratio with increasing ϵ is seen showing, without ambiguity, that the enhancement of $\frac{B_\phi\sigma_\phi}{B_\rho\sigma_\rho+B_\omega\sigma_\omega}$ is not P_T dependent as it was argued some years ago (7).

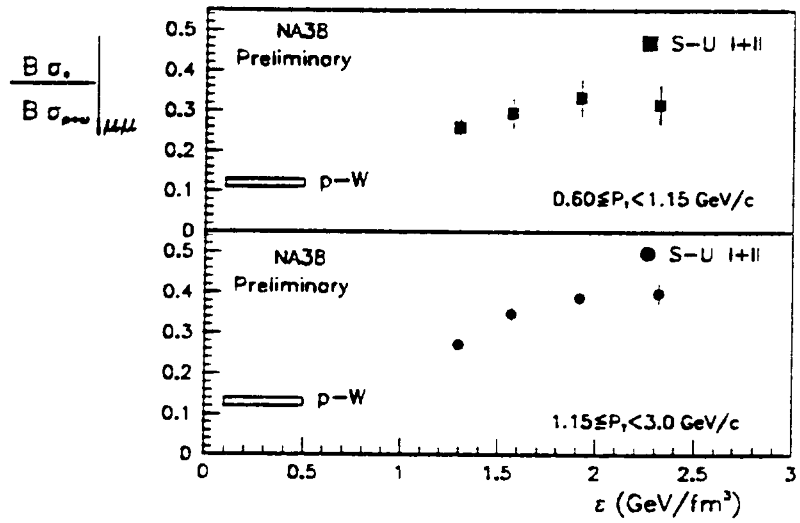

FIG. 6. $\frac{B_\phi \sigma_\phi}{B_\rho \sigma_\rho + B_\omega \sigma_\omega}$ ratio as a function of the energy density ϵ in $S-U$ collisions for 0.6≤ $P_{T\mu\mu}$ <1.15 GeV/c and 1.15≤ $P_{T\mu\mu}$ <3.0 GeV/c. The box areas represent the values measured in $p-W$.

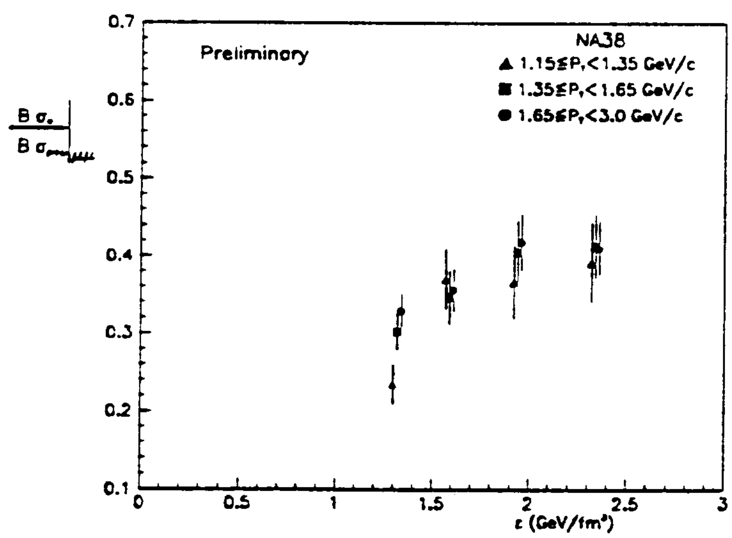

FIG. 7. $\frac{B_\phi \sigma_\phi}{B_\rho \sigma_\rho + B_\omega \sigma_\omega}$ ratio as a function of the energy density ϵ in $S-U$ collisions for 3 different $P_{T\mu\mu}$ regions.

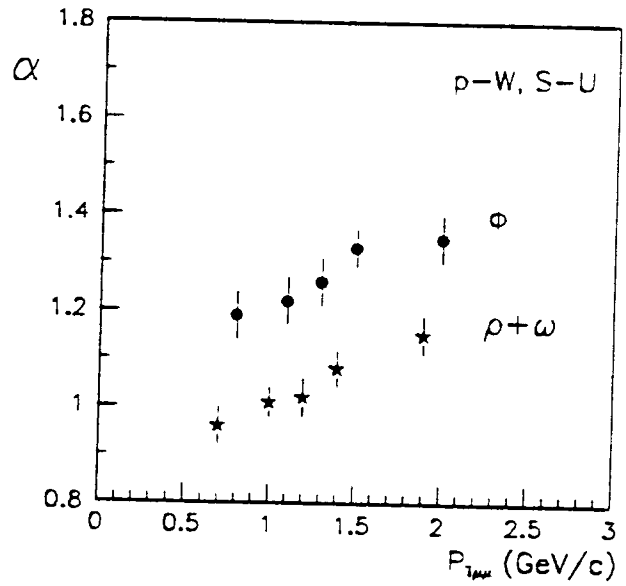

FIG. 8. A dependence of the resonances $\rho + \omega$ and ϕ as a function of the dimuon transverse momentum

The A dependence

Assuming the power law $\sigma_{SU} = \sigma_0(A_{beam} \cdot A_{target})^{\alpha}$, we measured the values $\alpha_{\rho+\omega}$ and α_{ϕ} as a function of P_T. The results are shown in Fig. 8. The Cronin effect (14) is seen for both resonances systems, but the α_{ϕ} value is systematicaly above the $\alpha_{\rho+\omega}$ value by approximatly the same amount in each P_T interval ($\Delta\alpha_{\phi,\rho+\omega} = \alpha_{\phi} - \alpha_{\rho+\omega} = 0.23 \pm 0.04 \pm 0.07$ for $P_{T\mu\mu} \geq 0.6$ GeV/c). From p-p and p-N experiments, an equal A-dependence for the ϕ and $\rho + \omega$ system is observed (15), i.e. $\Delta\alpha_{\phi,\rho+\omega} \approx 0$. This means that the resonances ϕ and $\rho + \omega$ have the same absorption in matter, and going from p-W to S-U interactions we do not see a bigger $\rho + \omega$ absorption ($\alpha_{\rho+\omega} = 1.00 \pm 0.02 \pm 0.11$, $P_{T\mu\mu} \geq 0.6$ GeV/c), but we observe a clear enhancement of the ϕ ($\alpha_{\phi} = 1.23 \pm 0.03 \pm 0.05$, $P_{T\mu\mu} \geq 0.6$ GeV/c).

CONCLUSIONS

NA38 collaboration reports in this paper the study of the $\rho + \omega$ and ϕ production in the dimuon channel, for p-W and S-U interactions at 200 GeV/nucleon, as a function of M_T, P_T and ϵ.

The transverse mass differential cross section's parametrization of the $\rho+\omega$ and ϕ resonances presents an inverse slope T which increases by 8% going from p-W to S-U reactions.

We observe a clear enhancement of the ratio $\frac{B_\phi \sigma_\phi}{B_\rho \sigma_\rho + B_\omega \sigma_\omega}$ comparing p-W to S-U collisions (by a factor of 3) and with increasing ϵ for any P_T region.

The A dependence measurements according to the power law: $\sigma_{SU} = \sigma_0 (A_{beam} \cdot A_{target})^\alpha$ give for $P_{T\mu\mu} \geq 0.6$ GeV/c and $E_T \geq 15$ GeV, $\alpha_\phi = 1.23 \pm 0.03 \pm 0.05$ and $\alpha_{\rho+\omega} = 1.00 \pm 0.02 \pm 0.11$. These values shows a ϕ enhancement in ion relative to proton interactions.

Finaly, we conclude that NA38 experiment observes unambiguously a strangeness enhancement in S-U collisions. This is found to be compatible with a Quark Gluon Plasma scenario (16). Interpretations based on secondary scattering processes in the framework of Hadron Gas formation (17,7) are rulled out. However, recent calculations, in RQMD model considering strong chromoelectric fields from string fusion and hadronic rescattering (18), presents for the ratio $\frac{B_\phi \sigma_\phi}{B_\rho \sigma_\rho + B_\omega \sigma_\omega}$ the same trend as our results.

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