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$\psi\prime$ and J/ψ production in p-U and S-U collisions at 200 GeV/nucleon*

NA38 Collaboration

M.C. Abreu[4], C. Baglin[1], A. Baldit[2], C. Barrière[2], M. Bedjidian[8], P. Bordalo[4], A. Bussière[1], J. Castor[2], T. Chambon[2], B. Chaurand[6], D. Contardo[8], E. Descroix[8], A. Devaux[2], O. Drapier[8], B. Espagnon[2], J. Fargeix[2], R. Ferreira[4], P. Force[2], L. Fredj[2], J. Gago[4], C. Gerschel[5], P. Gorodetzky[7], B. Grosdidier[7], J.Y. Grossiord[8], A. Guichard[8], J.P. Guillaud[1], R. Haroutunian[8], D. Jouan[5], L. Kluberg[6], R. Kossakowski[1], G. Landaud[2], D. Lazic[7], P. Liaud[1], C. Lourenço[4], L. Luquin[2], F. Malek[8], R. Mandry[8], R. Mazini[7], L. Peralta[4], J.R. Pizzi[8], C. Racca[7], S. Ramos[4], A. Romana[6], B. Ronceux[1], R. Salmeron[6], S. Silva[4], P. Sonderegger[3], X. Tarrago[5], J. Varela[4], F. Vazeille[2]

(1) LAPP, Annecy; (2) LPC, Clermont-Ferrand; (3) CERN, Geneva; (4) LIP, Lisbon;
(5) IPN, Orsay; (6) LPNHE, Palaiseau; (7) CRN, Strasbourg;
(8) IPN-Lyon, Villeurbanne

Presented by B. Ronceux (LAPP, Annecy)

Production and decay into two muons of $\psi\prime$ and J/ψ mesons is studied in p-U and S-U interactions at 200 GeV/nucleon. The ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ is found to be 0.0201 $\pm$ 0.0044 $\pm$ 0.0020 in p-U and 0.0093 $\pm$ 0.0011 $\pm$ 0.0013 in S-U. For S-U interactions, this ratio decreases by about 40% with increasing transverse energy. Our p-U result confirms previous measurements which show that the relative production of $\psi\prime$ and J/ψ in p-A interactions is independent of A. The results are discussed in the frame of QGP formation and final state absorption.

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Introduction.

The production of the $\psi\prime$ and J/ψ resonances in heavy ion collisions provides an interesting constraint for theoretical models studying the evolution of the dense and hot nuclear matter. Both resonances give information about the early stage of the primary interaction. In fact, their different formation times, radii, binding energies and interaction cross-sections should induce differences in their production rate. The survival probability of $\psi\prime$ compared to J/ψ was calculated in the frame of QGP formation and in the final state absorption model [1,2]. The models predict that the $\psi\prime$ is more likely to be suppressed than the J/ψ when the energy density reached in the collision increases.

The NA38 experiment measures both $\psi\prime$ and J/ψ through their dimuon decay channel in p-U and S-U interactions. The experiment makes use of high intensity proton and Sulphur beams (up to 5.10^8 ions/burst) interacting with a 20% of an interaction length fractionned Uranium target. The apparatus consists of a dimuon spectrometer, an electromagnetic calorimeter and a set of specific beam-control detectors [10,11].

Data analysis.

The data samples studied in this paper correspond to 5 different data taking periods which extend from 1987 to 1991. They amount to about 50% of the total data collected by experiment NA38. The use of several slightly different experimental set-ups with different mass resolutions and acceptances makes it impossible to treat all the data together. Data samples are therefore analyzed separately for each set-up.

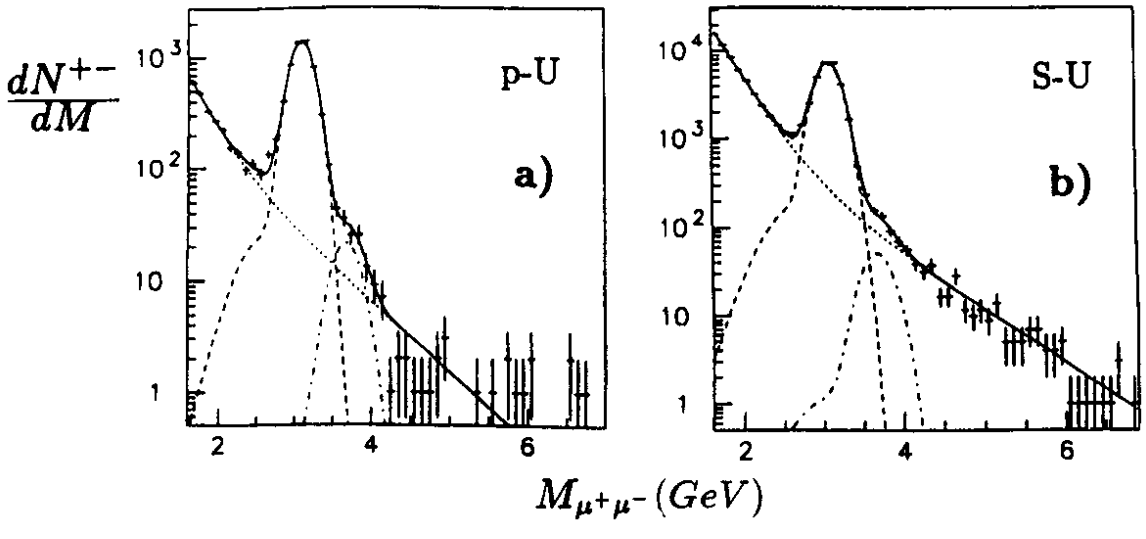

Figure 1: Typical invariant mass spectra of opposite-sign dimuons ($\mu^+\mu^-$) with $\psi\prime$, J/ψ and continuum contributions for p-U (a) and S-U (b) interactions.

The invariant mass spectra of the opposite-sign muon pairs are fitted between 1.7 and 7.0 GeV/c^2. In order to extract the $\psi\prime$ resonance, a phenomenological parametrization with 2 exponential terms is used to reproduce the mass continuum: the first term represents the dimuons due to the Drell-Yan process and the second term represents both

the opposite-sign background component and the other processes (for instance, $D\bar{D}$ decays). For the S-U data, a preliminary fit above 4.1 GeV/c^2 allows to fix the slope of the Drell-Yan process. The shapes of the resonances, as observed through the apparatus, are obtained by simulation techniques.
Figures 1 and 2 show that the fit with these 4 components gives a good description of the data.

In order to study the production ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ as a function of the neutral transverse energy, the E_T^0 distribution for S-U interactions is divided into 4 equipopulated bins (excluding $E_T^0 < 15$ GeV, where the target recognition procedure has low efficiency). The width of each E_T^0 bin is large enough to allow and neglect the differences in E_T^0 resolution of each subsample.

A systematical error in the $\psi\prime$ production rate arises from the evaluation of the high mass Drell-Yan slope; this contribution represents about 50% of the events in the $\psi\prime$ mass region for the S-U system and induces a 15% systematical error in the $\psi\prime$ rate calculation.

For each data sample the production rates of the $\psi\prime$ and J/ψ are calculated from the fitted contributions, the simulated acceptances of the apparatus and the efficiencies due to data reduction.

Results and discussion.

Figure 1 shows the opposite-sign dimuon mass spectra for both the p-U and S-U systems. It can be observed that the $\psi\prime$ contribution, relative to the other processes, is smaller for Sulphur than for proton induced reactions.
Figure 2 shows the invariant dimuon mass spectra as a function of E_T^0 in S-U interactions. The well-known J/ψ suppression with respect to the mass continuum [3] as well as the decrease of $\psi\prime$ compared to the other processes are observed between low and high E_T^0.

Table 1 shows the ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ for p-U and S-U data.

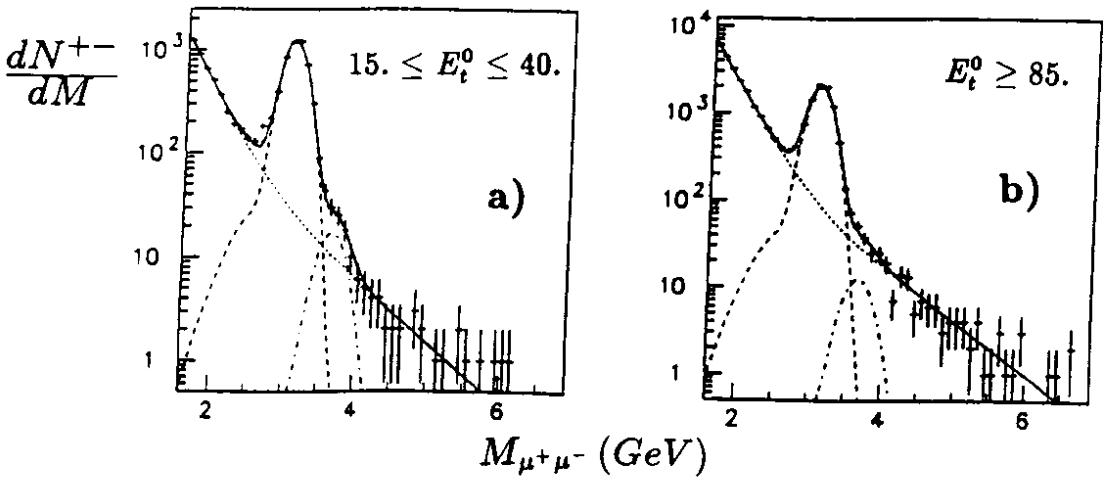

Figure 2: Invariant mass spectra of opposite-sign dimuons ($\mu^+\mu^-$) with $\psi\prime$, J/ψ and continuum contributions for S-U interactions: (a) low E_T^0, (b) high E_T^0 (for one subsample of the data).

It has been shown in p-nucleus interactions [4] that, at 800 GeV/n, the production of $\psi\prime$ as compared to J/ψ is independent of the atomic number A of the target.
Figure 3 presents the ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ measured by different experiments [5-9] for p-A collisions at different $\sqrt{s}$. Our p-U result at 200 GeV/n confirms that this ratio remains constant, within errors, for proton induced reactions.

As shown in figure 1, the ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ is 2 times smaller for S-U interactions than for p-U interactions. This suppression cannot be extrapolated from the observed p-A experimental results.

p-U	S-U				
	All E_T^0	$15.< E_T^0 <40.$	$40.< E_T^0 <62.$	$62.< E_T^0 <85.$	$85.< E_T^0 <200.$
		$< E_T^0 >= 27.$	$< E_T^0 >= 51.$	$< E_T^0 >= 75.$	$< E_T^0 >= 100.$
2.01±0.44 ±0.20	0.93±0.11 ±0.13	1.06±0.18 ±0.16	1.03±0.15 ±0.15	0.86±0.16 ±0.13	0.68±0.16 ±0.10

Table 1: The ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ (%) for p-U and S-U systems. E_T^0 is in GeV.

Figure 4 shows the ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ as a function of the energy density ϵ reached in S-U collisions (estimated with $\epsilon = \frac{3.<E_T^0>}{\Delta\eta\tau_0\mathcal{A}_\perp}$, where $< E_T^0 >$ corresponds to the average E_T^0 in each bin, $\Delta\eta$ is the pseudo-rapidity range where E_T^0 is measured, $\tau_0 \sim 1 fm/c$ is the formation time of the plasma and $\mathcal{A}_\perp$ is the overlap area of the target and the projectile, averaged over the E_T^0 range).
The $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ ratio decreases by about 40% with increasing energy density.

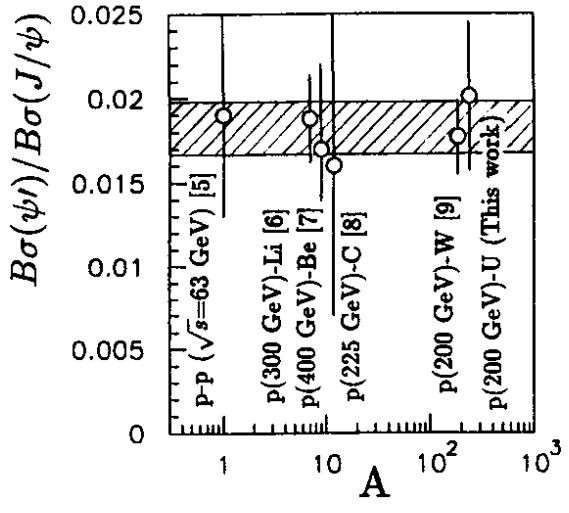

Figure 3: The ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ as a function of A in p-A interactions (we assume the same relative decay branching ratio to e^+e^- compared to $\mu^+\mu^-$ for $\psi\prime$ and for J/ψ). The horizontal line is the calculated average (0.0183±0.0015).

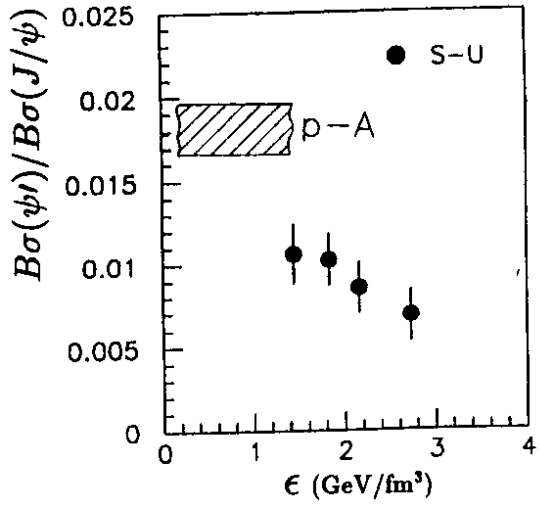

Figure 4: The ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ as a function of the energy density reached in S-U collisions. The shaded area is the average value for p-A interactions.

Preliminary calculations for $\psi\prime$ and J/ψ suppressions as a function of the energy density have been made [1] in the context of QGP formation and final state absorption. Theoretical predictions describe the observed evolution of the data. However, the present experimental and theoretical uncertainties do not allow more detailed conclusions. Higher experimental statistics, the increase of the temperature and reaction volume with the future Lead beam, and a more precise theoretical description is needed.

Conclusions.

This analysis presents the $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ production ratio obtained in p-U and S-U interactions. For p-U, our result confirms that $\psi\prime$ and J/ψ are suppressed identically in proton induced reactions independently of the target. The ratio $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ is about 2 times smaller in S-U than in p-U, indicating the existence of a suppression mechanism which does not occur in the p-A system. For S-U collisions, the $B_{\mu\mu}\sigma(\psi\prime)/B_{\mu\mu}\sigma(J/\psi)$ ratio decreases by about 40% as a function of the neutral transverse energy. The QGP and final state absorption models predict such a behaviour.
Experimental work is in progress to reduce both statistical and systematical uncertainties.

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