ϕ, ρ and ω production in Pb-Pb collisions at 158 GeV/c^2 per nucleon

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The production of low mass dimuons has been measured in Pb-Pb collisions at the SPS (CERN). (ϕ/(ρ+ω)) ratios have been studied with respect to the centrality of the collision. Preliminary results on ϕ and (ρ+ω) multiplicities as a function of the number of participants are presented. Values for the temperature T are deduced from the cross sections studies in the limited transverse mass M_t domain covered by the experimental apparatus.

The NA50 experiment is devoted to the study of the J/Ψ suppression in heavy ion collisions which could be a possible signature of the phase transition towards a quark gluon plasma (QGP) state of nuclear matter at high energy density.
Last results [1,2] of anomalous suppression in Pb-Pb collisions were a strong motivation to look to other possible information on the dimuon spectrum. Large statistics on dimuon pairs collected in the 1996 run allowed detailed investigation of the low mass (ϕ and (ρ+ω)) resonance region despite the limited M_t acceptance. The ϕ meson, which carries hidden strangeness, is of special interest for studies of strangeness production in this field. A strong ($s\bar{s}$) enhancement is predicted [3] in the case of a QGP formation. Due to its small rescattering cross section in the nuclear medium, the ϕ production will reflect the earlier time of its formation. It has also been studied in other experiments [4].

Details on the apparatus and the experiment can be found in previous publications [5]. The measurement of neutral transverse energy in the electromagnetic calorimeter was used to sort events in 9 centrality bins. The combinatorial background (2/3 of the events in the region of interest : 0.25<M<1.4 GeV/c^2) has been subtracted in the classical way described in [5]. A complete simulation of the experimental apparatus has been performed taking into account smearing and acceptance effects. Adjustments of source distributions on experimental data have been done for each variable (transverse mass Mt, mass M, rapidity Y, C.S. angles θ, φ) and for each component (ρ, ω ,ϕ, continuum) in the corresponding mass region.

A first phenomenological generation function for each variable V_i, depending on parameters p^i_j was used. The events were then reconstructed through the apparatus. A correction function defined as $f^i_{cor} = (dN/dV_i)_{experimental} / (dN/dV_i)_{reconstructed}$ was deduced and applied to the initial generation function which was then fitted in order to find the best values for the parameters p^i_j. The procedure was then carried out iteratively until stable values of parameters p^i_j were found along with a flat behavior of f^i_{cor}. Initial transverse mass (M_t) and rapidity (Y) distributions were taken as :

$$(dN/dM_t) \propto M_t^2 \, K_1(M_t / T) \text{ and } (dN/dY) \propto \exp(-Y^2 / 2\sigma^2)$$

The ϕ and ω mass distributions were assumed to be Breit-Wigner shapes whereas the ρ resonance was taken as being a Breit-Wigner multiplied by a phase space factor deduced from (ρ→2π) nonresonant background. The ratio ω/ρ is fixed assuming the same production cross sections for the 2 resonances. The continuum is considered globally with a $M^{-\alpha} \exp(-M/\beta)$ distribution.

Fits of the mass spectra were performed in various M_t domains and for the 9 centrality bins. The numbers of produced dimuons were extracted for each component in the kinematical domain (0 < y < 1. and -0.5 < cos θ < 0.5). A careful study of systematic effects (such as changes in M_t slopes, background subtraction and continuum deformation) was done, giving values lower than 9.5% for individual points . Statistical errors were evaluated for each M_t or E_t bin. The ϕ/(ρ+ω) ratio (in the μμ channel) is presented in figure 1 as a function of the number of participants. The latter is connected to the centrality of the reaction derived from the experimental transverse energy information. The error bars correspond to both systematic and statistical effects. For M_t above 1.5 GeV/c^2 this ratio increases smoothly with the centrality. This trend is observed in each M_t bin. This has already been observed [6,7] for lighter projectiles such as in S-U systems previously studied.

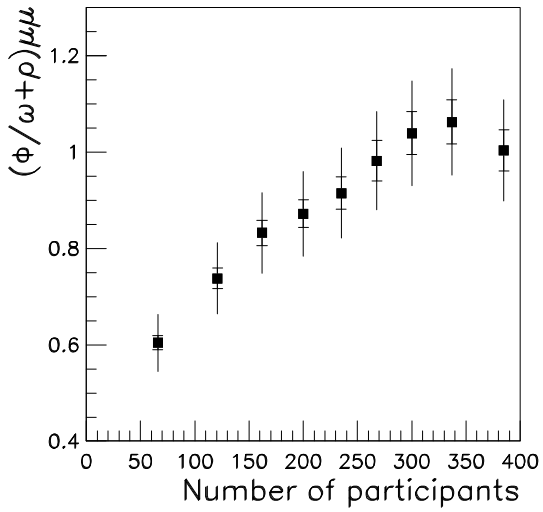

Figure 1 : $(\phi/(\rho+\omega))_{\mu\mu}$ ratio for the total Mt range : $1.5< M_t<3.2$ GeV/c^2 , as function of the number of participants.

No typical trends are observed for this ratio versus M_t which looks flat with respect to the transverse mass as shown for four E_t bins, in figure 2.

In 1996, minimum bias events were recorded, allowing to extract the multiplicities classically defined as the number of produced ϕ (resp. ρ+ω) per Pb-Pb collision.

Experimental values, as a function of the number of participants, are increasing for both ϕ and (ρ+ω) in the different M_t bins. This behavior can be studied more precisely by calculating the multiplicities per participant.

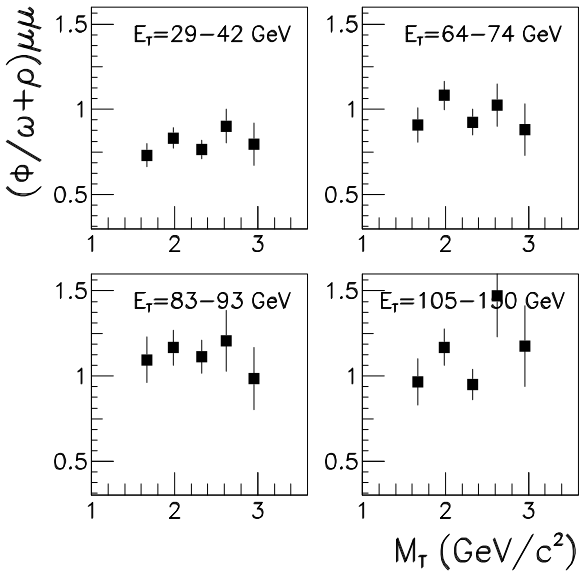

Figure 2 : $(\phi/(\rho+\omega))_{\mu\mu}$ ratio as function of the transverse energy for four different E_t bins

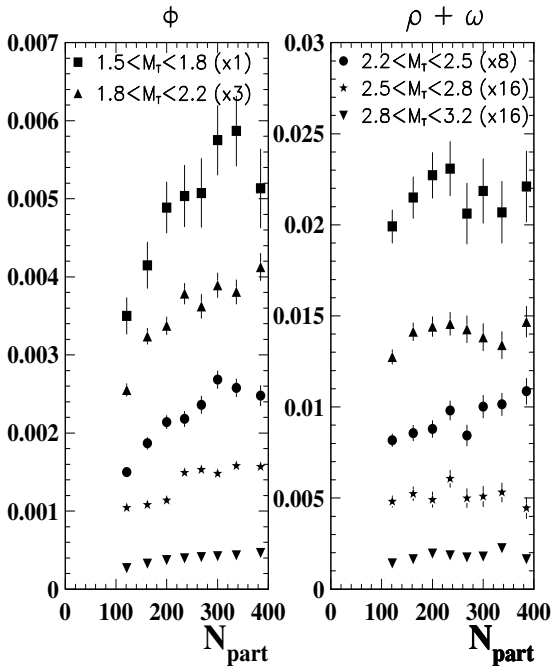

Figure 3 : Multiplicities per participant for the different M_t as function of the number of participants

This has been performed for each M_t bin for the ϕ and (ρ+ω) components. Results are presented for each M_t bin in figure 3[*)] and for the whole M_t domain in figure 4[*)]. It is clearly seen that the (ρ+ω) production has a linear behavior with respect to the number of participants. An additional increase of around 60% (figure 4) is observed for the ϕ resonance which flattens out at around 250 participants.

Finally, cross sections were extracted for both ϕ and (ρ+ω) components and studied as a function of the transverse mass for all centrality bins. This allows to extract the inverse slope T corresponding to the emission in a thermalized source model.

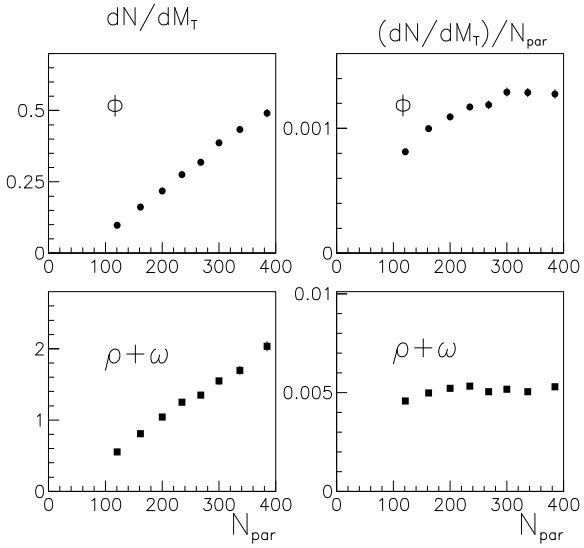

Figure 4: Multiplicities and multiplicities per participant for ϕ and $\rho+\omega$ components in the M_t range $1.5 < M_t < 3.2$ GeV/c^2

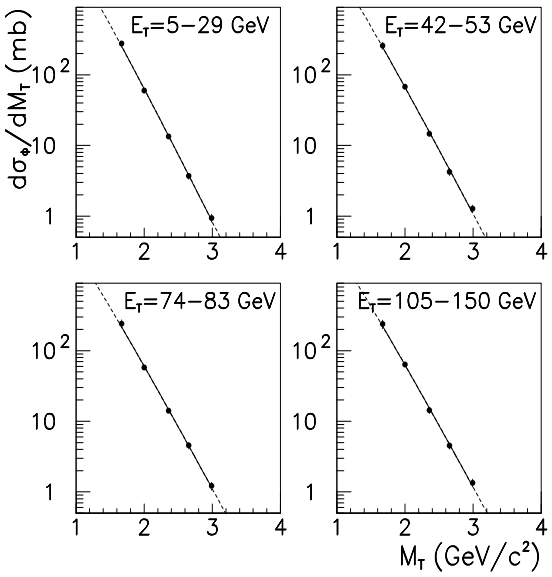

Figure 5: Cross sections as function of the transverse mass M_t for some E_t bins.

Experimental results on the ϕ yields are presented in figure 5[*)] together with the fit performed to extract the inverse slope, for 4 E_t bins. A temperature $T = 222 \pm 6$ MeV and $T = 219 \pm 5$ MeV for ϕ and $(\rho+\omega)$ respectively are found to be constant for all bins. Typical χ^2 values of 0.8 and 2.7 are obtained respectively.

To conclude, in the limited experimental window, ϕ and $\rho+\omega$ production have different increase rates in Pb-Pb collisions : the ϕ resonance increases more rapidly than the $\rho+\omega$ as a function of the centrality. This is confirmed by the multiplicity studies.
This observation, which is an indication of the increase of strangeness production in Pb-Pb collisions, might be related to other results in different channels and to the anomalous J/Ψ suppression observed in the same experiment.

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[*)] Values on figures 3 and 4 have been divided by the width of the M_t bin and are not integrated values for each bin, as presented in the talk. Values of cross sections, in figure 5 were also divided by the width of each bin.