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DILEPTON PRODUCTION IN RELATIVISTIC HEAVY ION COLLISIONS*

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In this contribution we will discuss the production of low mass dileptons. The current theoretical understanding will be briefly reviewed, emphasising possible in medium effects.

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1. Introduction

The study of low mass dileptons has recently received considerable interest. This has been triggered by the observation of enhanced production of dileptons with invariant mass around $400 - 500$ MeV in relativistic heavy ion collisions by the CERES collaboration [1, 2]. This enhancement has been studied using various models, ranging from thermal model to complicated transport models. All those calculations include the known hadronic decay channels into lepton pairs and, in addition, dilepton production via re-interaction of particles, most prominently pion annihilation. They find that pion annihilation accounts for a large part of the observed enhancement, while other channels such as the pion-rho scattering or the Dalitz decay of the a_1-meson are less important (see *e.g.* [3, 4]). In Ref. [3] a large variety of initial conditions for the hadronic fireball has been considered under the constraint that the final state hadronic spectra are in agreement with experiment. Surprisingly little variation has been found in the resulting dilepton spectra. Certain initial conditions would agree with the lower end of the sum of statistical and systematic errors of the CERES data for the sulfur on gold reactions. In [3, 5] in medium modifications of pions and the pion nuclear from-factor in a pion gas have been considered and have been found to be negligible. The conclusion of [3] and many other works (see [6] for a list of

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references) is that in order to reach the central data points of the S + Au measurement, additional in medium modifications need to be considered. Most of the attention received the suggestion of Li *et al.* [8], that a dropping of the mass of the ρ-meson with density — following, with some modifications, the original conjecture of Brown and Rho [7] — can reproduce the central data points. On the other hand, Rapp *et al.* [9] have extended the work of [3,10] to include also the effect of baryons for the in medium modification of pions. The present status of those considerations (see contribution of W. Wambach, these proceedings) is that the in medium change of the pion dispersion relation leads only to a small enhancement, whereas the inclusion of baryon resonances which couple directly to the rho meson appear to be able to increase the yield substantially. Most important is here the $N^*(1520)$ resonance, as first pointed out by the Giessen group [11]. The p-wave resonances, which have been first considered by Friman and Pirner [12] appear to play a lesser role. We should note, however, that the calculation of Steel *et al.* [13], although similar in spirit, finds a much smaller effect due to baryons.

In this contribution we want to revisit the CERES data, particularly those for the system Pb + Au [2]. These data have been analysed to provide not only an invariant mass spectrum but also transverse momentum spectra and thus may give new insight into the relevant production mechanisms. We also will present arguments concerning the importance of baryons. According the work of Rapp *et al.* baryons seem to be the most important source for the low mass enhancement. In contradiction to that, our estimates in [3] found the baryons to be irrelevant.

2. The Pb + Au data

In this section we present some new results for the dilepton spectra for Pb + Au. The calculation is similar to that carried out in [3] and we refer to this reference for details. A new element is the inclusion of the channel $\pi + \rho \rightarrow \pi + e^+e^-$ [14]. Using vector dominance this process is related to the elastic $\pi + \rho \rightarrow \pi + \rho$ scattering, which gives rise to the collisional broadening of the rho meson, as first discussed in [15]. We have attempted to include the effect of the collisional broadening into our transport model, by calculating the collisional width as a function of the local pion density. This certainly is a crude method and needs to be refined in the future.

In Fig. 1 (left panel) we show the resulting invariant mass spectra together with the CERES data [2], where only the statistical errors are shown. We find a reasonable overall agreement. However, around 350 MeV our results are a little below the data. On the right panel of Fig. 1 we compare our results for the transverse momentum spectra for pairs in the mass range

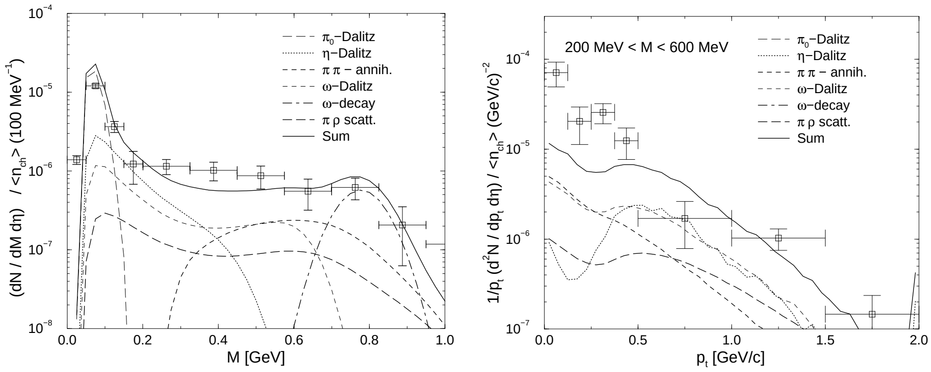


Fig. 1. Dilepton invariant mass spectrum (left panel) and transverse momentum spectrum (right panel). The data are from Ref. [2].

of 200 MeV $<$ M $<$ 600 MeV. Apparently the enhancement in the data (as compared to the calculation) is located at small transverse momenta.

This can also be seen in Fig. 2 where we show the invariant mass spectra for the transverse momentum interval $p_t < 400\,\mathrm{MeV}$ (left panel) and $p_t > 400\,\mathrm{MeV}$ (right panel). While the calculation agrees rather well for the high momentum spectra, for the low momentum spectra again the discrepancy is apparent.

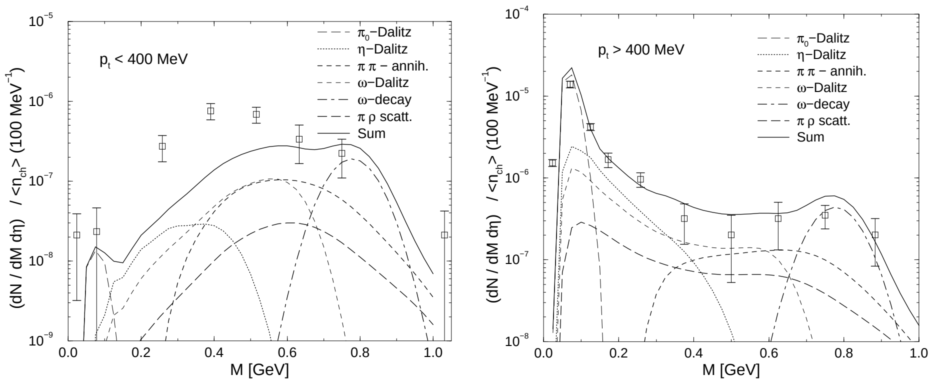


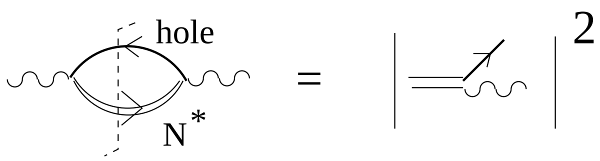
Fig. 2. Dilepton invariant mass spectra for transverse momenta smaller than 400 MeV (left panel) and larger than 400 MeV (right panel). The data are from Ref. [18].

In the meantime, however, new data have been presented by the CERES collaboration at the International Nuclear Physics conference in Paris, August 1998 [19]. In comparison with the published data shown above, the new data are lower, in particular in the intermediate mass region. Also, the enhancement at low transverse momenta is not present in the new data. Overall, our calculation presented above agrees rather well with these new data, except around the rho/omega mass, where we are slightly to high. This would be a rather interesting result, because the onset of chiral restoration would lead to a reduced strength at the rho peak. However, the number of omega mesons is rather unconstrained in these calculations so that the missing strength could simply be due to an overestimate of omega mesons. Anyhow, at this point it is to early to draw any conclusions. First the new data need to be thoroughly digested.

3. The role of baryons

The work of Rapp *et al.* has emphasized the role of baryons as a possible source for additional dileptons. They consider in medium modifications of the current-current correlator, the imaginary part of which is directly related to the dilepton production rate. Following the suggestion of the Giessen group [11] Rapp *et al.* also found that the contribution of the $N^*(1520)$-hole diagram, as plotted below, is the most important one. However, as shown in the plot, the imaginary part of this diagram is nothing but the Dalitz-decay of the $N^*(1520)$.

The contribution of the Dalitz decays of baryons has already been estimated in Ref. [3]. In this estimate, the formula for the branching ratio of photon to Dalitz decay of the Δ [16] has been extended to higher masses. In order to arrive at an conservative estimate of an upper limit the fraction of higher lying resonances has purposely been overestimated by a factor of two. The photon decay width has been chosen to be 1 MeV, which again is on the large side. The resulting dilepton spectrum has then been compared with that of the omega, in order to minimise the effect of the detector acceptance. The ratio of these yields is shown in Fig. 3. The baryons hardly contribute half as much as the ω-Dalitz. Considering the contribution of the omega Dalitz as shown in Fig. 1 it seems that the baryons are anything but irrelevant.



So what is the difference between this estimate and the results of Rapp *et al.* Several possibilities come to mind:

- The $N^*(1520)$ has a considerably larger Dalitz decay width than the extrapolation from the Delta decay width would predict. This might be possible, in particular, because the $N^*(1520)$ couples rather strongly to the ρ-meson. This is presently being investigated [20], but one should keep in mind that the above estimate would have to be at least a factor of ~ 10 off.

- Rapp *et al.* sum the RPA-type Dyson-series for these diagrams. So in principle there could be collective effects, which are ignored in the simple calculation of the Dalitz decay. It appears, however, rather unlikely that at the temperatures under consideration, collectivity can play an important role.

- Certainly one discrepancy is the baryon to pion ratio used in the two calculations. Rapp et all use an initial baryon density of about 2 ρ_0. For the pions they use a temperature of $T = 170\,\mathrm{MeV}$ and vanishing chemical potential. This leads to a pion to baryon ratio of about 3/2, whereas a ratio of close to 6 is observed in experiments. Unless the pion number changes drastically during the expansion — and there is not indication that this should be the case [17] — the relative importance of the baryons is thus overestimated in these calculations. The estimate of [3], on the other hand was based on a realistic pion/baryon ratio. This point will be addressed in detail in [20].

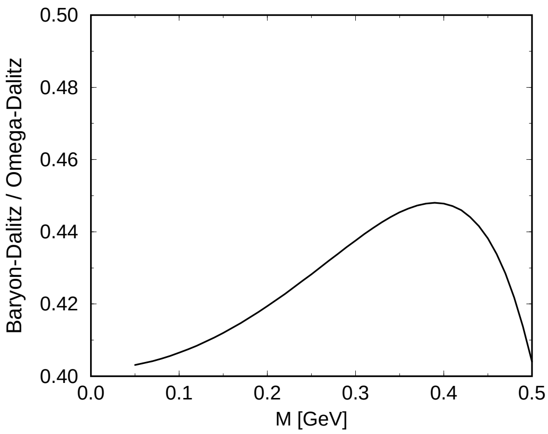


Fig. 3. Ratio of baryon-Dalitz decay over ω-Dalitz decay.

All this points are specific to the environment created in a CERN energy heavy ion collision. At lower energies or in proton/pion nuclear reactions the density effects could very well be large. This will be investigated in the near future by the HADES detector at the GSI.

4. Conclusions

At this point it is very hard to draw any firm conclusions as the new CERES data need first to be thoroughly investigated. Taking these data at face value, however, it appears that no or only small in medium corrections are needed in order to explain the data. This would be somehow unfortunate, although, as shown in [3] in medium modifications due to the presence of pions indeed give rise only to small corrections. Certainly, all these calculations are rather unconstraint. For instance the number of omegas can be chosen within a considerably wide range. While these uncertainties have already been addressed, a measurement with a mass resolution which is sufficient to constrain the number of omegas in the final state would reduce these uncertainties to a large extent. This would then provide the basis for the search of more subtle effects which, one would think, should be there.

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