NA38/NA50 results on the low mass dimuon spectra

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The dimuon mass spectrum produced in p-U collisions is well described, for masses below 1.5 GeV, as a superposition of light meson decays (the *hadronic cocktail*), the decays of charmed mesons and quark-antiquark annihilation into muon pairs. When these results are extrapolated to sulphur induced collisions, a small excess is observed over the whole mass region, particularly pronounced in the ϕ peak.

The dilepton mass spectrum below 1.5 GeV, referred in the following as the low mass region (LMR), is generally believed to consist primarily of a superposition of light meson decays into leptons. The HELIOS-1 experiment studied the muon and electron pairs produced in p-Be collisions at 450 GeV, describing them on the basis of decays of light neutral mesons [1]. More recently, the CERES and TAPS collaborations measured the dielectron mass spectra in p-Be and p-Au collisions at 450 GeV, confirming that the data are well reproduced by the expected contributions of light meson decays [2]. In this work we report the results of a similar analysis applied to the dimuon data collected by NA38 in p-U, S-S and S-U collisions at 200 GeV per incident nucleon. The main difference with respect to the CERES measurement is that the phase space domain is limited to high transverse masses, while CERES is dominated by low transverse momenta.

The detector is basically a dimuon spectrometer with a toroidal magnet, 8 multiwire proportional chambers for the muon track reconstruction and 4 scintillator hodoscopes for trigger purposes. The data used in this work were taken with segmented active targets, where a surrounding hodoscope of ring scintillators identifies the interaction subtarget. A hadron absorber, essentially made of carbon, is placed between the target and the spectrometer. The combinatorial background induced by pion and kaon decays in the opposite sign mass spectrum is estimated from the simultaneously collected like sign pairs, using the formula $N_{BG} = 2R\sqrt{N^{++}N^{--}}$, where N^{++} (N^{--}) is the number of pairs made of two positive (negative) muons. In p-U we used R=1.2, as suggested by a dedicated experimental study with a tungsten target. In S-U the multiplicity is high enough to justify R=1, while for the S-S system we used R=1.1. In p-U data the signal is 5 to 10 times higher than the background, up to the ϕ peak; in S-S and S-U the average signal/background ratio in the same mass range is 0.67 and 0.54, respectively.

The analysis is performed in a restricted kinematical domain in order to keep the acceptances higher than 1% for every process. The selected events have $0 < y_{CM} < 1$, $|\cos\theta_{CS}| < 0.5$ and $m_T > 2(y_{CM} - 0.55)^2 + 0.9$ GeV, where y_{CM} is the rapidity in the center of mass frame, θ_{CS} is the polar decay angle in the Collins-Soper frame, and m_T is the transverse mass. The acceptances were calculated with a Monte-Carlo simulation of the apparatus response and vary, in the low mass region, between 1% and 5.5%. The resolution of the spectrometer is 86 MeV at a mass of 500 MeV.

The dimuon mass spectra are normalized using the J/ψ cross section, $B\sigma^{\psi}$, directly measured in p-U and S-U. For S-S we interpolate $B\sigma^{\psi}$ with the formula $\sigma_{AB} = \sigma_0(AB)^{\alpha}$, where $\alpha = 0.92$ [3].

We have adapted a Monte Carlo code developed by CERES to generate the expected contributions to the dimuon spectra from decays of light mesons. The generated dimuons are then filtered through a program that simulates the apparatus response and are subjected to the same cuts as applied to the experimental data. The light meson decays that give a significant contribution to the dimuon mass spectrum are the Dalitz decays of the η, ω and η' and the 2-body decays of the η, ρ, ω and ϕ.

The production cross sections relative to the π^0 yield have been taken from ref [2], and incorporate information previously provided by the NA27 [4] and HELIOS-1 [1] experiments. For the ϕ we use the ratio ϕ/ω of ref. [4].

The normalization of the expected processes is obtained by scaling them with the average π^0 multiplicity and the inelastic cross section. The pion multiplicity is calculated as $0.5 \times \langle\pi^0_{NN}\rangle \times \langle N_P\rangle$, where the nucleon-nucleon pion multiplicity, $\langle\pi^0_{NN}\rangle$, and the number participating nucleons, $\langle N_P\rangle$, are calculated according to ref. [5]. The values obtained agree with the measured multiplicities within 10%, except for S-S where the difference is $\sim 20\%$. The p-U inelastic cross section is taken from the PDG tables, while for A-B collisions we use the geometrical parametrization $10\pi r_0^2 (B^{1/3} + A^{1/3} - \delta)^2$ mb, with $r_0 = 1.35$ fm and $\delta = 1.1$.

The transverse momentum of the light mesons is generated with $m_T\, K_1(m_T/T)$, where K_1 is the modified Bessel function. For p-U collisions we use $T = 190$ MeV, as determined by a fit to the η meson p_T distribution measured by CERES/TAPS in p-Be collisions. For the sulphur induced collisions we use $T = 220$ MeV. The rapidity distributions have the functional form $1/\cosh^2(a\, y)$, very similar to a gaussian of width

$\sigma = 3/(4a)$. For pions, this width is calculated using Landau's prediction $\sqrt{\log \gamma_{\rm proj}}$ while, for the other mesons, we scale this value with the ratio of the maximum allowed rapidities: $\sigma(x) = \sigma_\pi \; y_{\rm max}(m_x)/y_{\rm max}(m_\pi)$. The resulting values are in reasonable agreement with the available measurements. We assume that in p-U collisions the peaks of the rapidity distributions are shifted towards the target hemisphere by 0.3 for the ϕ and by 0.45 for the η, ρ, ω and η'. In the less asymmetric S-U system, the values used are 0.2 and 0.3, respectively. The J/ψ, being a hard process, is kept always at mid-rapidity.

The mass distributions for the processes $\omega \to \mu^+\mu^-$ and $\phi \to \mu^+\mu^-$ are described by the Gounaris-Sakurai parametrization; for the ρ, in order to have a more reasonable description of its high mass tail, we use a formula presented in ref. [6].

The form factors for the Dalitz decays of the light mesons have been measured by the LEPTON-G collaboration [7]; the parametrization for the η is based on a pole approximation, while for the ω and the η' a Breit-Wigner function is used.

The decays of the charmed mesons into muons give a non negligible contribution. To take this source into account we generated charmed mesons decaying into muons with PYTHIA 5.7 [8]. We have used the GRV LO 92 [9] parton distribution functions and a charm cross section in pp collisions at 200 GeV of 6.4 μb, with a linear dependence of the cross section on the projectile and target mass numbers.

The p-U data show an excess with respect to the previously described expected sources (hadronic cocktail plus $D\bar{D}$ decays), of 30% below 400 MeV and of 50% in the range 400–650 MeV. A possible explanation of this excess is quark-antiquark annihilation into low mass dileptons. Such an extrapolation to lower masses of the Drell-Yan process could be important in our kinematical window, since it would be less affected by the high transverse mass cut than the rather soft muon pairs originated from Dalitz decays. This contribution should be negligible in the case of CERES, where no selection on the transverse mass is made. A computation of such a process would require extrapolating the Drell-Yan calculation to a non-perturbative region and remains to be done. We tried to get a rough estimation of its contribution by extending the calculation made by PYTHIA down to the lowest Q^2 allowed by the GRV LO 92 parton distribution functions. The normalization is determined by the mass region above the J/ψ.

Figure 1 shows how the importance of the $q\bar{q}$ annihilation process relative to that of

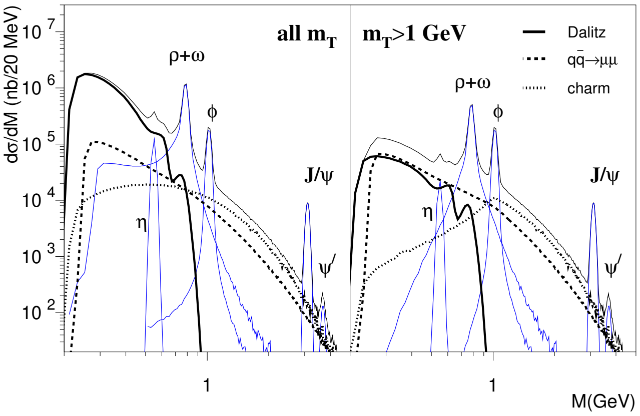

Figure 1. Generated mass spectrum before and after applying the cut $m_T > 1$ GeV.

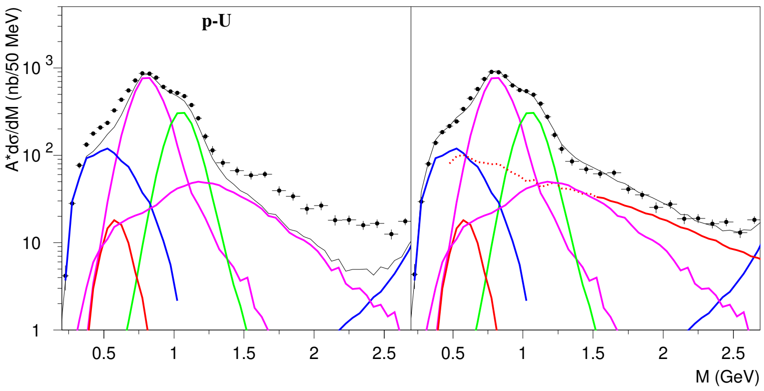

Figure 2. Dimuon mass spectrum in p-U before (left) and after (right) adding the $q\bar{q}$ annihilation process

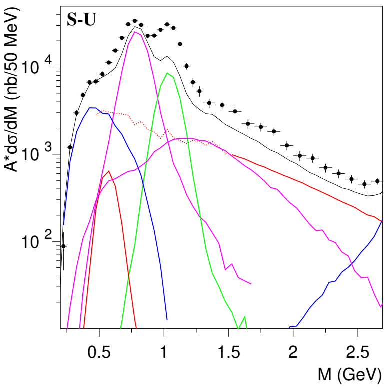

Figure 3. Dimuon mass spectrum in S-U collisions

the Dalitz decays changes with the introduction of a cut on the transverse mass. When the $q\bar{q}$ annihilation is added to the "expected" sources, the p-U data are well accounted for, as shown in Fig. 2. The extrapolation to the S-S and S-U collisions, Fig. 3, reveals a small excess extending through the whole low mass region, whose value (and statistical uncertainty) is reported in Tab. 1 for different mass bins. To fit the S-U ρ/ω and ϕ peaks, their cross sections relative to pions must be increased by 1.23 and 3.20, respectively. The larger excess seen by CERES might be due to the difference in the transverse momentum regions probed by the data. Future data, extending through a broad p_T range, will help to clarify these observations.

Table 1
Ratio data/sources in different mass intervals

Mass (GeV)	p-U (no $q\bar{q}$)	p-U	S-S	S-U
0.40-0.65	1.50 ± 0.03	1.05 ± 0.02	1.1 ± 0.1	1.24 ± 0.03
0.65-0.95	1.09 ± 0.01	1.02 ± 0.01	1.16 ± 0.04	1.29 ± 0.02
0.95-1.20	1.11 ± 0.02	1.03 ± 0.02	1.5 ± 0.1	2.31 ± 0.04

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