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Abstract: We study the space-time dependence of muon pair production from dense, non-equilibrium pion matter in the framework of a Boltzmann type transport model which properly includes effects of Bose statistics. Starting from an initially supersaturated pion gas with a large positive effective chemical potential we find that this pion chemical potential stays approximately constant during the evolution. As a consequence such a scenario leads to an increased dilepton yield near the kinematical threshold for muon pair production via pion annihilation. Depending on the lifetime of the dense hadron matter formed in relativistic heavy ion collisions, this component can be observed above the background of muon pairs from resonance decays and the ρ, ω bump. In such a way the measurement of the di-muon invariant mass spectrum could help to understand the initial state and the dynamical evolution of ultrarelativistic heavy ion collisions.

1 Introduction

There is strong theoretical as well experimental evidence that the recently performed heavy ion collision experiments ($E = 200$ A·GeV) at the CERN SPS lead to the formation of an initially dense state of strongly interacting matter. The important question, however, if this primordial state consists of a plasma of partially deconfined quarks and gluons has not yet found an unambiguous answer. Even so many proposed quark-gluon plasma signals have actually been observed in these experiments (for example J/Ψ-suppression, enhanced strange particle production, ϕ-enhancement, increase in transvers momenta of the emitted particles) alternative explanations based on purely hadronic scenarios can not be ruled out.

In the same spirit a peculiar spectral property of pions, namely an appearently enhanced production at very low transverse momentum ($p_\perp < 200$ MeV) [1], when compared to pp collisions at the same energy, has stimulated a lot of theoretical activity. Since the dynamical evolution of the dense zone is still matter of debate, there is yet no commonly accepted solution to the question about the origin of the low p_T pion enhancement. A number of different models have been proposed to analyze and explain these effects. Although rather different in their dynamical content, these models have in common the assumption that initially a hot and dense hadron matter system is formed, which subsequently expands and finally decays into the observed particles, which are mostly pions. The main distinction between the various models, however, is connected to the question if the observed phenomenon is a remnant of the initial state and therefore carrys information of the primordial phase of the nuclear collision process or if the phenomenon is a consequence of the final state evolution of the hadronic "fireball". Within the first category, some authors argue that the low-p_T pion enhancement could be associated with the initial formation of supersaturated pion matter created by the fragmentation of overlapping strings [2, 3] or even the hadronization processs of a quark gluon plasma blob [4]. During its subsequent evolution the expanding hot hadron matter may not be able to reach local chemical eqilibrium since the the pion - pion interaction at low center of mass energies is mainly elastic and therefore conserves the number of pions. In such an environment the collision rate could become considerably large and might rapidly evolve towards condensation in momentum space [4]. In the language of thermodynamics this means that local kinetic (thermal) equilibrium could be achieved but no chemical equilibrium. As a consequence this pion fluid develops a finite pion chemical potential, leading to an excess of pions at low momenta as $\mu_\pi \to m_\pi$.

Within the class of scenarios where the low p_T enhancement is essentially a final state effect there are models [5] which employ kinematic effects, like collective transverse expansion of matter in local (thermal and chemical) equilibrium, or models [6] which try to explain the phenomenon mainly as result of heavy resonance decays and do not consider collective transverse flow at all.

A somewhat different scenario is proposed in Ref. [7] where the authors argue that initially the system starts out as a hot and dense gas of hadrons, predominantly resonances, and chemical equilibrium is lost only during the final stage of the evolution process. Since hadrons interact strongly and are basically emitted at the end of the nuclear collision process, both scenarios can lead to the same final state and a distinction between different dynamical scenarios based only on the measurement of secondary hadron spectra seems not be possible.

On the other hand, electromagnatic probes like direct photons and lepton pairs represent messangers of the whole space-time evolution of the nuclear collision process [8] and may provide additional useful information. It was pointed out previously [9, 10], that the production of dileptons with invariant masses in the range $2m_\pi \leq M \leq m_\rho$, according to the process of pion annihilation $\pi^+\pi^- \to \rho \to \gamma^* \to \mu^+\mu^-$, is very sensitive to the presence of dense pion matter and can lead to a sizeable enhancement of lepton pairs which exceeds the background of Dalitz pairs once this matter is sufficently longlived (i.e. $\Delta t \geq$ 4-5 fm). In contrast to recent work [9] we shall investigate in detail the influence of the space - time evolution of non-equilibrium pion matter on the dilepton yield. In particular we focus here on the time evolution of the effective pion chemical potential in the framework of Boltzmann like kinetic theory supplemented by the appropriate Bose occupancy factors. In accordance with previous authors we shall assume that heavy ion collisions at CERN-SPS energies generate a collision zone in the central region which is dominated by mesonic degrees of freedom, predominantly pions. We shall solve the Boltzmann equation that describes the evolution of this pion matter. This allows us to estimate the behaviour of the pion chemical potential and the temperature under different initial conditions. Finally we analyze the consequences for di-muon production taking into account consistently the contribution stemming from the Dalitz decays of hadron resonances.

2 Pion dynamics

We start our considerations assuming that kinetic theory gives the adequate framework to describe the evolution of dense pion matter. We shall further assume, that this pion matter is produced not very far from the state of local thermodynamical equilibrium. To be specific, we employ the Boltzmann equation in the relaxation time approximation

$$p^\nu \partial_\nu f = -\tau_{rel}^{-1} u^\nu p_\nu (f - f_{eq}) \tag{1}$$

where $p^\nu = (m_\perp \text{ch}y, m_\perp \text{sh}y, \vec{p}_\perp)$ is the pion four momentum, expressed via the rapidity $y = (1/2)\ln((E+p_z)/(E-p_z))$, the tansverse momentum $p_\perp$, transverse mass $m_\perp = \sqrt{m_\pi^2 + \vec{p}_\perp{}^2}$. The quantity u^ν stands for the matter's four velocity and we assume that the matter expands essentially longitudinal along the beam axis, i.e. $u^\nu = (\text{ch}\Theta, \text{sh}\Theta, \vec{0})$ with Θ as the longitudinal flow rapidity. As indicated by the latter choice, we exploit the space - time symmetry of the one-dimensional scaling solution of Bjorken [12], where $t = \tau \,\text{ch}\,\eta$, $z = \tau\,\text{sh}\,\eta$, and where the space-time rapidity $\eta = (1/2)\ln((t+z)/(t-z))$ coincides with the flow rapidity $\theta = (1/2)\ln((1+v_z)/(1-v_z))$ of the matter, i.e., $\eta = \Theta$ (τ is the proper time, while t is the *cms* time coordinate and z the longitudinal space coordinate). With these particular set of coordinates and dynamical assumptions the Boltzmann equation takes the form

$$\partial_\tau f + \frac{\text{th}\xi}{\tau}\partial_\xi f = \tau_{rel}^{-1}(f - f_{eq}). \tag{2}$$

For convenience we have introduced the variable $\xi = \eta - y$. The details of the $\pi\pi$ interaction are accumulated in the relaxation time $\tau_{rel}(\tau)$, where the proper time dependence enters via the implicit dependence on the distribution function f or its moments. The solution of eq. (2) reads

$$f(p_\perp,\xi,\tau) = e^{-\varphi(\tau)}[f_0(p_\perp,\xi_0) + \int_{\tau_0}^{\tau} \frac{d\tau'}{\tau_{rel}} e^{\varphi(\tau')} f_{eq}(p_\perp,\xi',\tau')] \tag{3}$$

$$\varphi(\tau) = \int_{\tau_0}^{\tau} \frac{d\tau''}{\tau_{rel}(\tau'')}, \quad \tau\,\mathrm{sh}\xi = \tau'\,\mathrm{sh}\xi' = \tau_0\,\mathrm{sh}\xi_0,$$

$$f_0(p_\perp,\xi) = [\exp\{(m_\perp\,\mathrm{ch}\xi - \mu_0)/T_0\} - 1]^{-1},$$

$$f_{eq}(p_\perp,\xi,\tau) = [\exp\{(m_\perp\,\mathrm{ch}\xi - \mu(\tau))/T(\tau)\} - 1]^{-1}.$$

We have used here a thermal distribution function for the initial distribution f_0 for basically two reasons. The first one, based more on technical considerations, is that the transverse hadron spectra as measured in p-p collisions can be rather well fitted by such a distribution. However, from the physics point of view the more important argument is that like to study in some detail the effect of a hot and dense non-equilibrium pion state on the production of muon pairs. Therefore, we chose a maximum disorder state f_0 in eq. (3). Other arguments in favour of the choice can be found in Ref. [11, 15].

The reference equilibrium distribution function f_{eq}, which is used to mimic the collision term, has five parameters which are fixed by the prescribed flow pattern and the two matching conditions

$$n = g(2\pi)^{-3}\int d^3p\, f = g(2\pi)^{-3}\int d^3p\, f_{eq}, \tag{4}$$

$$\epsilon = g(2\pi)^{-3}\int d^3p\, E\, f = g(2\pi)^{-3}\int d^3p\, E\, f_{eq} \tag{5}$$

($g = 3$ for pions) which express particle (pion) number and energy conservation. It is easily checked that the matching condition (4) implies that the integral over eq. (1) results in particle number conservation, i.e. $n(\tau)\tau = const = n(\tau_0)\tau_0$. In analogy, the energy-weighted integral over eq. (1) results in the energy conservation (5) which cannot be integrated in closed form due to the appearence of the longitudinal pressure [11]. Instead one can perform the energy weighted momentum integral over eq. (3) to get a closed equation for the energy density evolution

$$\epsilon(\tau) = e^{-\varphi(\tau)}[\epsilon_0\, h(\frac{\tau_0}{\tau}) + \int_{\tau_0}^{\tau} \frac{d\tau'}{\tau_{rel}(\tau')}\epsilon(\tau')h(\frac{\tau'}{\tau})e^{\varphi(\tau')}]. \tag{6}$$

Similar to Ref. [11] we employ the approximation $v_\pi \cong 1$ in deriving the function $h(x) = \frac{1}{2}\left(x + \frac{\mathrm{arsin}\sqrt{1-x^2}}{\sqrt{1-x^2}}\right)$. These evolution equations determine the time dependence of the chemical potential $\mu_\pi(\tau)$ and temperature $T(\tau)$ by numerical inversion of

$$\begin{aligned} n(\mu_\pi,T) &= T^3 g z^2 (2\pi^2)^{-1}\sum_{l=1}^{\infty}\exp\{\frac{l\mu_\pi}{T}\}K_2(lz)l^{-1}, \\ \epsilon(\mu_\pi,T) &= T^4 g z^2 (2\pi^2)^{-1}\sum_{l=1}^{\infty}\exp\{\frac{l\mu_\pi}{T}\}\left(3K_2(lz)l^{-1} + K_1(lz)\right)l^{-1}, \end{aligned} \tag{7}$$

where $K_{1,2}$ are modified Bessel functions and $z = m_\pi/T$ (we use units with $\hbar = c = 1$).

In order to solve eqs. (4,5) explicitly we must specify the relaxtion time $\tau_{rel}(\tau)$. Analyzing $\pi\pi$ scattering at low and medium energies, Gavin [11] argues that $\tau_{rel}(\tau) = \alpha^{-1}\tau$ summarizes the essential features, with α a coupling parameter. This form of the relaxation time with $\alpha = 2$ and 4 for the S + S and O + Au reactions respectively, was also used in Ref. [3] to arrive at a good fit to the measured pion transverse momentum spectra. Note, however, that this parametrization does not include a freeze-out stage in the one-dimensional motion. Only if the later three-dimensional motion causes an expansion faster than $\tau_{exp} \propto \tau$ the collsion rate drops below the expansion rate and matter freezes out. Since we expect the contribution from this short freeze-out stage to be small we think that the present scenario is adequate. Results of the numerical solution of eq. (6) are displayed in Fig. 1. We have fitted some representative curves by the following polynomial forms:

$$\epsilon(s)\, s = \begin{cases} h(s^{-1})^{0.7}\, s^{-0.08} & \text{for } \alpha = 0.5, \\ h(s^{-1})^{0.25}\, s^{-0.2} & \text{for } \alpha = 2, \\ h(s^{-1})^{0.1}\, s^{-0.3} & \text{for } \alpha = 5, \end{cases} \qquad s = \tau/\tau_0. \tag{8}$$

The solutions are bounded by $\epsilon(s)s = h(s^{-1})$ for $\alpha \to 0$ (free streaming regime) and $\epsilon(s)s = s^{-1/3}$ for $\alpha \to \infty$ (hydrodynamical regime). For lifetimes $\tau < 5$ fm, which realistically can be achieved in present relativistic heavy ion collisions at CERN-SPS energies, and for which our approach to neglect the transverse motion is justified, the evolution of the energy density is not very sensitive to the coupling parameter. This also implies, that there is no huge difference between the free streaming and the hydrodynamical regime.

Using the equation of state (7) one finds the time evolution for the chemical potential and temperature as displayed in Fig. 2. Clearly, since we have introduced an additional degree of freedom, namely the pion chemical potential, we must expect that the temperature evolution is affected by this quantity. As can be seen from Fig. 2a the temperature $T(\tau)$ - at fixed coupling parameter α - drops faster for larger initial chemical potentials due to the additional work of the more dense medium. If the initial chemical potential is fixed then the system cools faster if α becomes larger. The evolution of the chemical potential depends sensitively on the relaxation velocity (see Fig. 2a). Slow thermalization (small values of α) causes a strong dilution of the pion matter, i.e., the chemical potential decreases and might even become negative. To wit, a negative chemical potential means that the particle species is below the local chemical equilibrium abundance. Faster equilibration causes roughly a constant chemical potential, while very fast equilibration causes an increase of the chemical potential. Important thing to note, however, is that the coupling parameters α as advocated in Ref. [2], allow the chemical potential to remain approximately on the initial level. This implies that we get a glimpse into the primordial stage of the reaction.

Therefore, in what follows we use $\mu_\pi(\tau) \approx \mu_\pi(\tau_0)$ and the proper time one-dimensional evolution of temperature $T(\tau) = T_0(\tau_0/\tau)^{1/3}$ [12] as convenient approximations in the case of short life times.

3 Di-muon production from dense pion matter

Having now the time evolution of the distribution function at our disposal we can calculate the dilepton rate from pion annihilation in hadron matter. In the kinetic approach it is given by

$$\frac{dN}{d^4x\, d^4Q} = \int \frac{d^3p_1}{(2\pi)^3}\frac{d^3p_2}{(2\pi)^3}\, f_{\pi^+}(x,p_1)\, f_{\pi^-}(x,p_2)\, v\, \sigma_{\pi^+\pi^-}(M^2)\, \delta^4(Q-p_1-p_2) \tag{9}$$

where $Q^\mu = (p_1+p_2)^\mu$ is the four momentum of the lepton pair $v = \frac{M^2}{2}(1-\frac{4m_\pi^2}{M^2})^{1/2}\frac{1}{E_1E_2}$ is the relative flux velocity of the colliding pions. Assuming vector meson dominance [13] the cross section takes the form

$$\sigma_{\pi^+\pi^-}(M^2) = \sigma(M^2)\, F_\pi^2(M^2)\, (1-\frac{4m_\pi^2}{M^2})^{1/2} \tag{10}$$

where

$$F_\pi^2(M^2) = \frac{1.2\, m_\rho^4}{(M^2-m_\rho^2)^2+\Gamma^2 m_\rho^2} \tag{11}$$

is the pion electromagnetic form factor ($m_\rho = 775$ MeV, $\Gamma = 115$ MeV) and

$$\sigma(M^2) = \frac{4\pi}{3}\frac{\alpha^2}{M^2}(1+\frac{2m_\mu^2}{M^2})(1-\frac{4m_\mu^2}{M^2})^{1/2} \tag{12}$$

denotes the electromagnetic annihilation cross section ($\alpha = \frac{1}{137}$). In order to proceed we would have to solve eq. (9) with the distribution functions (3) supplemented by the maching conditions (4) and (5). However, as has been shown in Refs. [14, 15] the rate is rather well approximated when f_{eq} is used instead of f. The reason is, that due to the matching condition eq. (4), f_{eq} can be considered as fit to the actual f and that for the given initial distribution function $f(\tau_0)$ the momentum spectrum is dominated by the exponential behavior. This does not hold, however, for other initial conditions. In what follows we shall replace the actual f by f_{eq}, which introduces a tremendous simplification, but only a small error.

Under this assumption, introducing space-time rapidity variables and making extensive use of longitudinal boost invariance, eq. (9) leads to the following spectrum for di-muon pairs with rapidity $Y = 0$.

$$\frac{dN}{dM^2\, dY\, dM_\perp^2} = \frac{R^2\alpha^2}{96\pi^2}(1+\frac{2m_\mu^2}{M^2})(1-\frac{4m_\mu^2}{M^2})^{1/2}(1-\frac{4m_\pi^2}{M^2})\, F_\pi^2 \times \tag{13}$$

$$\int_{\tau_0}^{\tau_{dec}} d\tau\, \tau \left(\frac{2\pi T}{M_\perp}\right)^{1/2} \exp\{-\frac{M_\perp}{T}\}\, J_H,$$

$$J_H = \frac{T}{(M_\perp^2-M^2)^{1/2}}[\exp\{-\frac{2\mu_\pi}{T}\}-\exp\{-\frac{M_\perp}{T}\}]^{-1}\log\left\{\frac{[x_- - \exp\{\frac{\mu_\pi-M_\perp}{T}\}][x_+ - \exp\{\frac{-\mu_\pi}{T}\}]}{[x_+ - \exp\{\frac{\mu_\pi-M_\perp}{T}\}][x_- - \exp\{\frac{-\mu_\pi}{T}\}]}\right\}$$

$$x_\pm = \exp\{\frac{-E_\pm}{T}\}, \quad E_\pm = \frac{1}{2}[M_\perp \pm (M_\perp^2-M^2)^{1/2}(1-\frac{4m_\pi^2}{M^2})^{1/2}]$$

After having specified the parameters R, τ_0, τ_{dec}, $\mu_\pi(\tau_0)$ and T_0 we can calculate the dilepton yield from pion annihilation assuming various different initial conditions.

As shown in Fig. 3 the finite chemical potential $\mu_\pi > 100$ MeV enhances the yield by an order of magnitude or more. This offers the chance that the pion annihilation process exceeds the background processes. A smaller chemical potential does not alter the yield too much, as compared with the yield from equilibrium pion gas, and therefore the background processes would dominate [16]. Before we can draw conclusions we have to include sources of background which could mask this annihilation contribution.

4 Background processes

Since the prominent features of the invariant-mass di-muon distributions, as measured in pion and proton induced reactions, are the ρ–ω peak and a large enhancement between the dilepton threshold and $M \sim 600$ MeV the question comes up if the di-muon production by pion annihilation can be really observed above this background. It is therefore mendatory to come to a satisfactory description of those processes which are responsible for the low mass di-muon continuum. For quite a long time there has been some controversy as to whether the more trivial sources like the Dalitz decays $\eta \to \gamma\mu^+\mu^-$, $\omega \to \pi^0\mu^+\mu^-$ alone can account for the observed enhancement [17]. Presently it is, however, fair to say that a main reason for the puzzle concerning the low mass dilepton continuum can be traced back to severe background problems and uncertanties concerning inclusive cross sections and kinematic distributions of those resonances which finally decay into lepton pairs via the Dalitz decays. New data, in particular the identification of the η and η' mesons, have changed the situation about the strenght of a possible low mass di-muon continuum considerably. According to a new analysis [18] the η Dalitz decay background had been underestimated by approximately a factor 2-4 in previous analysis of the data. The measured larger η and η' abundances are more in line with the picture of a thermalized fireball in chemical equilibrium, with a temperature consistent with the slope of the p_T-spectra. For that reason we have included nearly all possible dilepton decay modes of the pseudoscalar and vector mesons and shall assume that these processes are sufficient to account for the low mass continuum. We shall not go into detail of these cumbersome calculations and unhandy equations and ask the interested reader to consult [9]. The essential assumptions are that the decaying hadron resonances are in thermal as well as chemical equilibrium at freeze-out and all hadrons and resonances decouple at the same instant of time. As a consequence of this assumptions the ρ mesons carry a chemical potential $\mu_\rho = 2\mu_\pi$ due to the reaction $\rho \rightleftharpoons \pi^+\pi^-$ which can be assumed to be locally in equilibrium as the elastic pion scattering amplitude is dominated by p-wave ρ meson exchange in the s-channel.

A further important ingredient turned out to be the proper inclusion of the electromagnetic formfactors describing the coupling of the intermediate photon to the hadrons participating in the decay.

5 Results

After having specified the path we take within our calculation we can now proceed to discuss the observable consequences of our approach for the di-muon yield. In order to stay close to the recently performed nuclear collision experiments at the CERN-SPS we shall take furtheron those parameters which had been used succesfully to fit the pion transvers momentum distributions [2], i.e. we choose as break-up conditions $T_f = 160$ MeV, $\mu_\pi(\tau_f) = \mu_\pi(\tau_0) = 120$ MeV and $R = 4$ fm for a $S - S$ collision. Once these final state parameters are fixed the lifetime τ_f of the system is given in terms of the initial state parameters $\tau_f \simeq \tau_0(T_0/T_f)^3$. As usual, we take the initial proper time where the evolution starts as $\tau_0 = 1$ fm. The only free quantity left over is the initial temperature T_0.

In Fig. 4 we display the total yield $dN/dMdY|_{Y=0}$ of dimuons (full line) for the two choices $T_0 = 180$ MeV and 200 MeV which correspond to rather short lifetimes for the fluid due to the comparatively high freeze-out temperature. We observe that even for these short lifetimes as many muon pairs are produced by pion annihilation as produced via the decays of hadron resonances after decoupling (broken line). Clearly visible is an enhancement in the region above the threshold for dilepton production via pion annihilation. It approaches a plateau in the region $2m_\pi$ - m_ρ for increasing initial temperatures. In contrast to the higher-mass dileptons the low-mass dileptons probe also the lower temperature region, or in other words, the lifetime of the hadron phase.

However, we should take the foregoing discussion with some care as our results indicate that the mean free path (or mean time between subsequent collisions) is so short, that the approach treating the pions as free on-shell particles might need improvements, and further modifications of the pion properties should be taken into account [4, 9].

A different possibility we have not discussed here is related to the appearance of a mixed phase between quark and hadron matter in the nuclear collision which could increase the lifetime of the hadron phase quite considerably, leading to an ever larger enhancement of the di-muon yield. Work in this direction is in progress. In any case the observation of an enhanced di-muon yield in the invariant mass region between the two pion threshold and the $\rho - \omega$ peak points towards new and interesting physics and might allow to look directly into the early stage of the nuclear collision process. In this way it provides another important piece of information which can be used to come to a better understanding of the nuclear collision dynamics at high energies. In the final Fig. 5 we compare experimental data [19] for p + W and S + W reactions at CERN-SPS. Indeed, when normalizing the spectra in the ϕ region and taking into account the observed enhancement by roughly a factor of 3 in central nuclear collisions, one observes an enhancement of the di-muon yield around 600 MeV invariant mass for the S + W collsions. This is in line with the above presented scenario since for p + W collisions one cannot expect too much collectivity of the produced secondary particles.

We have not compared our calculations directly with the experimental data since the measuring procedure necessarily contains some cuts in phase space which we think do not change the qualitative behavior but make a detailed quantitative comparison at the present stage impossible. We like to mention here that a more refined analysis of the presented data indicate [20] that the enhancement of muon pairs in the low mass region becomes even stronger when data are selected which are closer to the central rapidity region. For this reason we postpone a detailed comparison of our model with the data to a future publication.

With respect to the heavier projectiles (as envisaged in lead beam project at CERN-SPS) and for the higher bombarding energies (as planned in RHIC and LHC projects) we expect an even higher collectivity due to the higher available multiplicities, and therefore a stronger increase of the di-muon enhancement.

6 Conclusion and outlook

In summary, we have calculated the dilepton yield in the low mass region above the threshold $\pi^+\pi^- \rightarrow \mu^+\mu^-$. Special emphasis was given to the space-time dependence of the production process. We find a strong enhancement in case of a scenario where initially a superdense pion fluid is formed. The enhancement increases with increasing initial temperatures T_0 and lifetimes of the hadron matter. This allows us to get information directly from the initial stage of the nuclear collision process.

If the recently put forward interpretation of the pion low $p_\perp$ enhancement due to the initial formation of superdense pion matter is correct then also an enhanced dilepton yield around 600 MeV should be observed.

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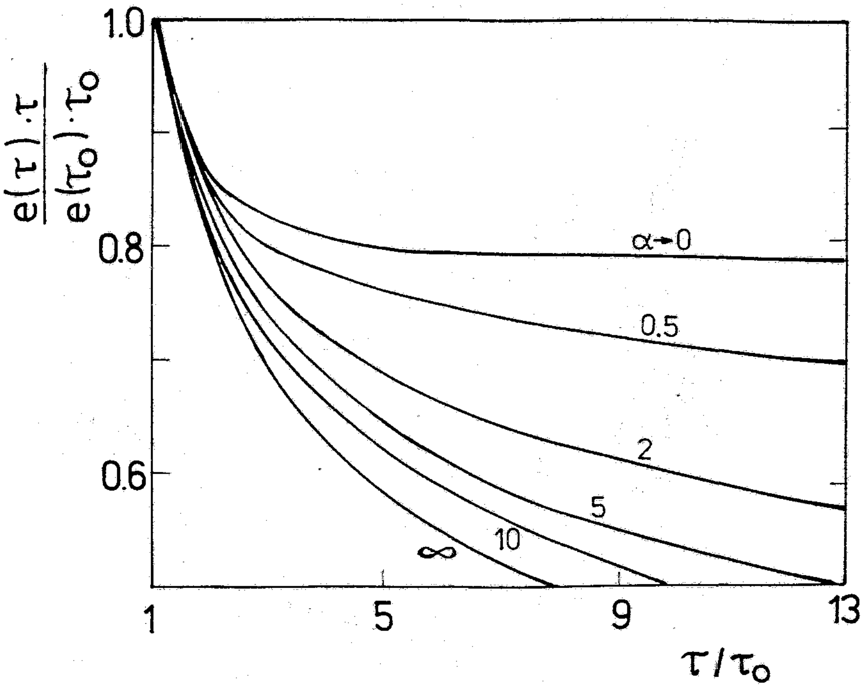

Fig. 1: The proper time evolution of the energy density for different coupling parameters α.

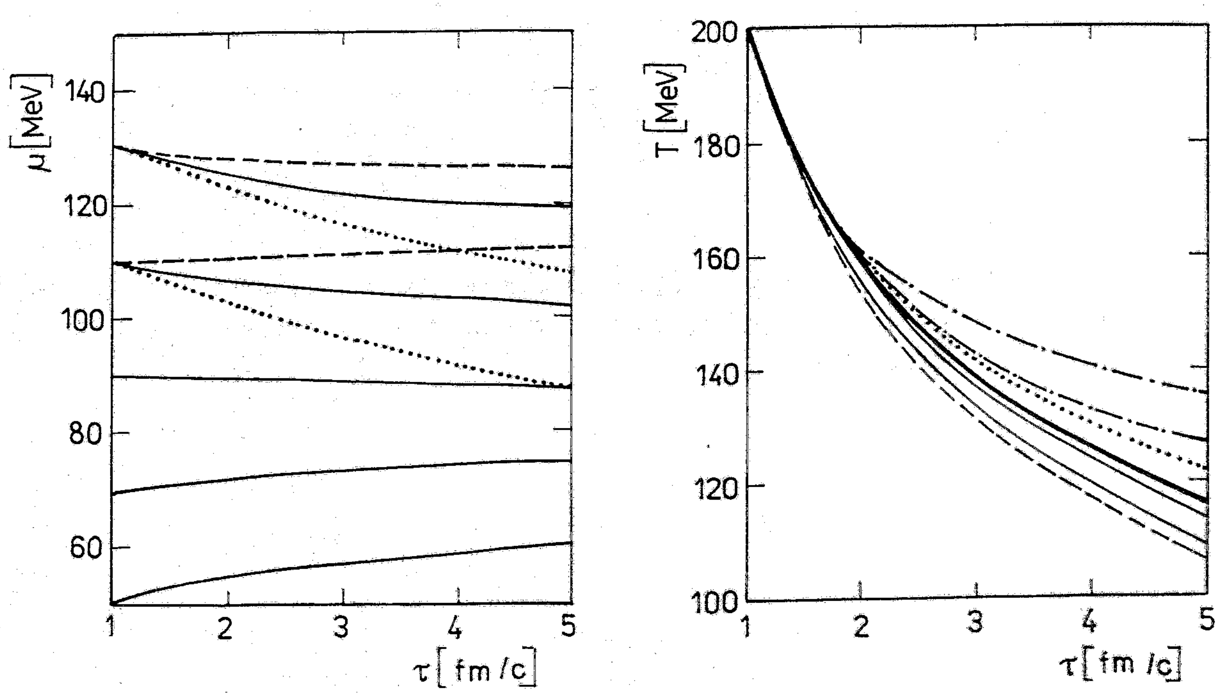

Fig. 2: The time evolution of the chemical potential (a) and temperature (b) for different coupling strengths (dotted/full/dashed lines correspond to $\alpha = 2/5/10$). In (a) the additional lines are: dash-dotted: $\alpha = 0.5$; thick line: $T(\tau) \sim \tau^{-1/3}$; if there are pairs of same type then the upper/lower one corresponds to $\mu_\pi(\tau_0) = 50/130$ MeV, otherwise $\mu_\pi(\tau_0) = 50$ MeV. The initial values are $T_0 = 200$ MeV and $\tau_0 = 1$ fm/c.

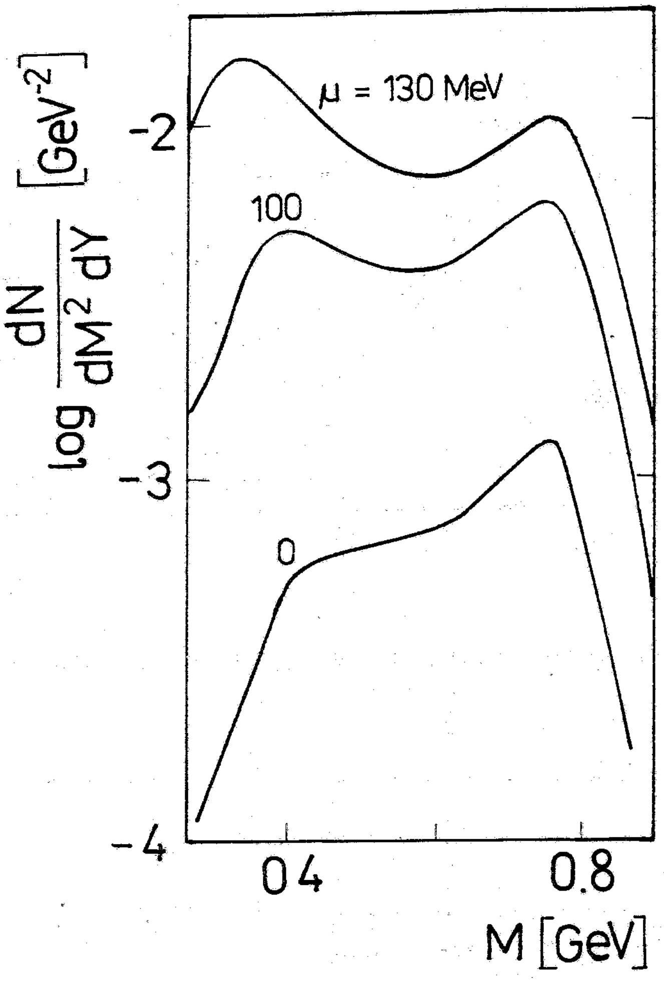

Fig. 3: Dilepton yield as function of invariant mass for different pion-chemical potentials. The initial values are $T_0 = 200$ MeV and $\tau_0 = 1$ fm/c. The freeze-out temperature T_f is here 120 MeV, and $R = 7$ fm.

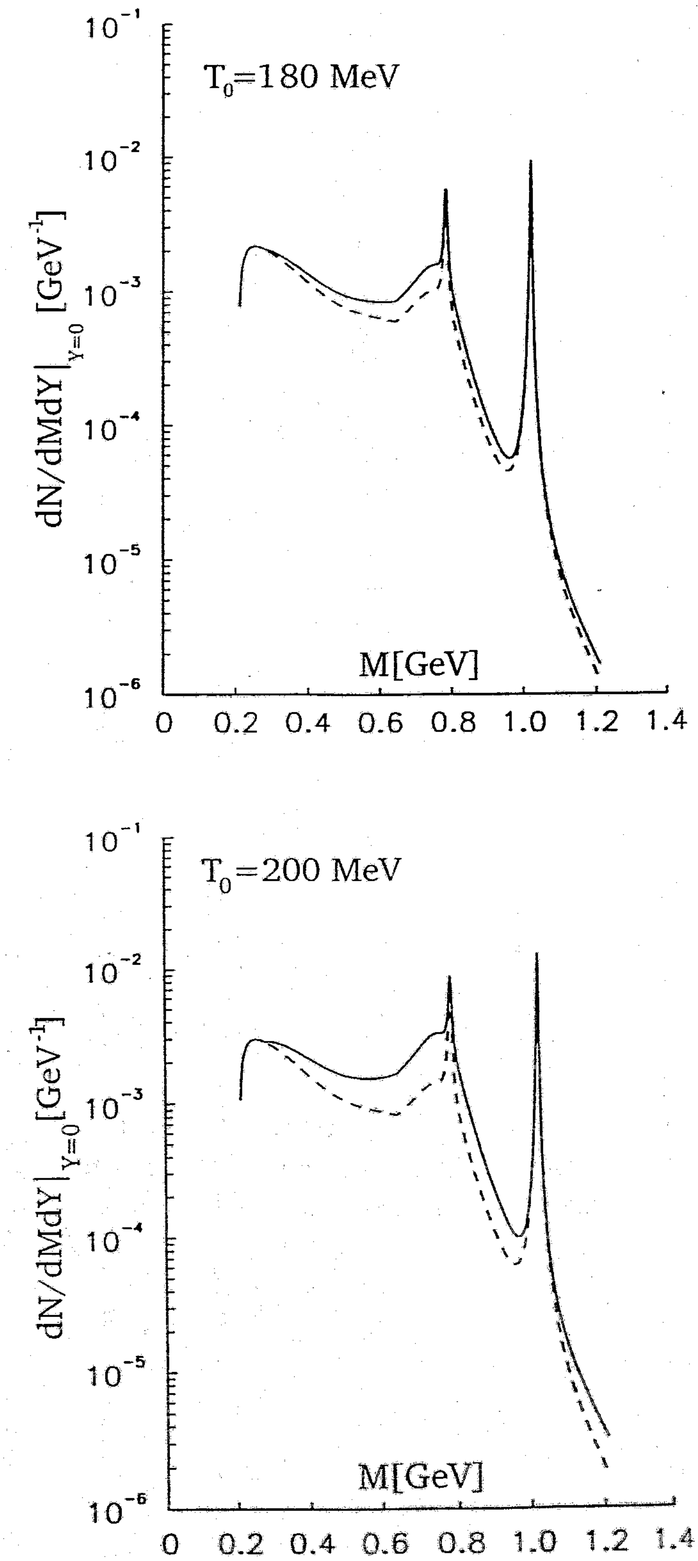

Fig. 4: The total dilepton yield (full line) as function of the invariant mass for $T_0 =$ 180 MeV (upper panel) and $T_0 = 200$ MeV (lower panel). The dashed line shows the contribution of the decays only.

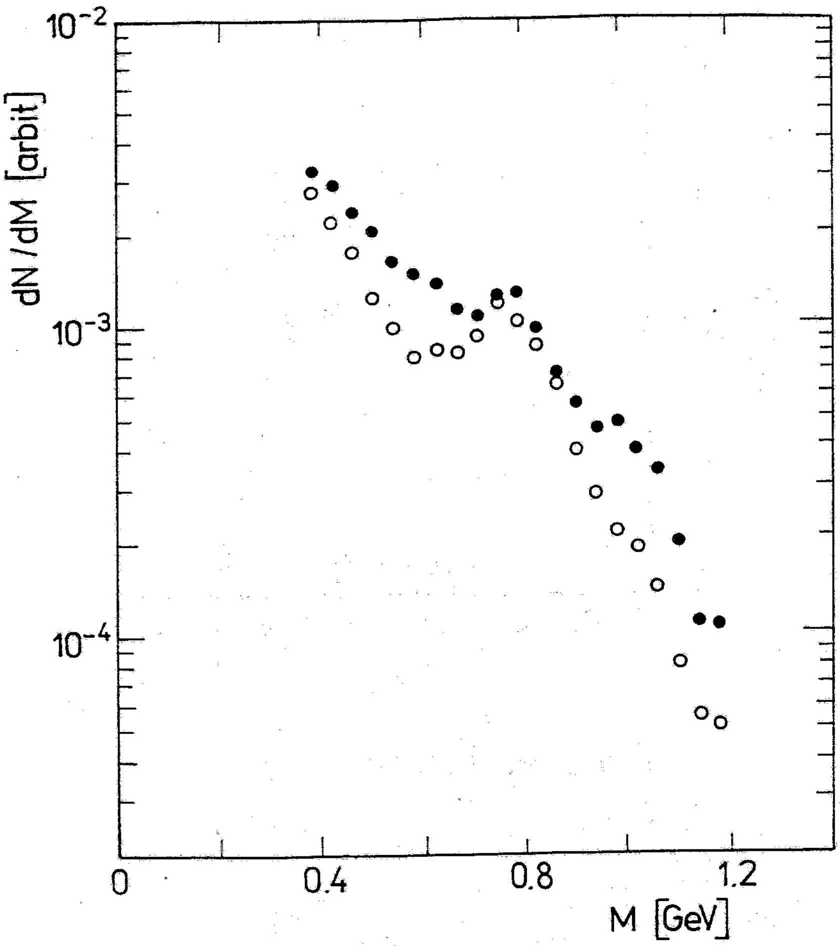

Fig. 5: Preliminary experimental data [19] for the reactions p + W (dots) and S + W (full circles) at 200 A·GeV beam energy. The data are normalized in the ϕ region taking into account the observed enhancement by roughly a factor of 3.