Final Report

1 Development of the Transport Model

To understand the differences of different transport models, multiplicity, rapidity and transverse momentum distributions from different programs simulating heavy ion reactions at kinetic energies of around 1 AGeV have been compared. If the same inputs are used, the programs yield quite similar results but differ in details. Some of the differences are understood in terms of the implementation of different physical approaches in the programs, and others, less important, remain to be explained. Despite of these differences the programs agree on some important physical results: The pions are almost exclusively produced by resonance decay. Subthreshold meson production is due to the same reaction as in free space and becomes possible because at least one of the collision partners has gained energy in collisions before. The programs furthermore agree on the stopping of matter, the dependence of the K+ squeeze out on its in-medium potential and on the softness of the density dependence of the effective nuclear potential[1].

For developing our model we worked on the collisional term. In a resonance model all the production channels were coupled and fitted together to the experimental scattering data. We use 26 resonances and their 11 decay channels. We built the collisional broadening in. In matter particles collide, therefore, they gain extra width, which is usually not considered in such models, because its calculation is rather tedious. For vector mesons this width may be rather important.

We, furthermore, introduced spectral functions for vector mesons, and let them propagate in our transport model. For their evolution we used dynamical equations derived from the Kadanoff-Baym-equation and built in our transport code. This step is really necessary if we want to study medium effects on particles with long lifetime like the omega meson. We showed that our approach is energy-momentum conserving and in vacuum particles regain their vacuum properties [2].

2 Strange particle production

$K^{\pm}$ and ϕ meson production in proton-nucleus (pA) collisions has been calculated within our transport model. It is shown that the nucleon-hyperon strangeness transfer channel is essential and a mildly repulsive K^{+} and a strongly attractive K^{-} potential. The role of three-body reactions has been investigated within the medium. The target mass dependence of production is predicted to give important information on the in-medium properties of all three mesons[3].

The production of strange mesons in collisions of Ar+KCl at a kinetic beam energy of 1.756 AGeV is studied within our transport model. In particular, ϕ, K^{+} and K^{-} yields and spectra are compared to the data measured recently by the HADES collaboration and the ϕ yield measured previously by the FOPI collaboration. Our results are in agreement with these data thus presenting an interpretation of the subleading role of ϕ decays into K^{-}'s and conrming the importance of the strangeness-exchange channels for K^{-} production. [4]

3 Dilepton Production

We calculated dilepton production in different models. In a simple, but very well tuned model, IQMD, for relativistic heavy ion collisions. We calculated dileptons at HADES energies [6]. We add all the channels which may be relevant at that energies. We include vector meson production perturbatively, the cross sections were fitted to experimental data. The model describes the HADES data very well with vacuum properties of vector mesons, and leave not much space for in-medium modification of vector mesons. The advantage of this model was that all the channels were fitted separately to experimental data, in such a way very good fit could be obtained. The disadvantage of this approach is that any extrapolation e.g. mass shift of the produced mesons cannot be included in a well defined way.

In one of our work, we studied how can we observe medium modification of vector mesons in the dilepton mass spectrum. We found that the simple mass spectrum is not enough for observing even strong effects. One has to use at least twofold differential dilepton spectrum to see any effect on the omega meson. We showed that even in such spectra the modification of the rho cannot be observed [7].

To reduce the theoretical uncertainties, we studied some of the channels from the background. We showed that in the Delta Dalitz-decay contribution there is at least of an order of magnitude theoretical uncertainity and in the bremsstrahlung a factor of four, too. I pointed out the necessity of a microscopical model for $pp \to ppe^+e^-$ [5] and compared to the experimental 3 dimensional dilepton spectrum to understand the relative strenghs of the separate components and give relyable input for models of heavy ion collisions. This work was presented in a Dilepton-workshop in GSI 2008.07.5 and a workshop in Sardinia 2008.09.11.

Our model described in the previous section could also describe the HADES and the DLS data. Unfortunatelly, even strong modification of vector mesons will be washed out in the final dilepton spectrum [2].

4 $\rho - A_1$-mixing in matter

With T. Hatsuda we studied the mixing of the ρ and A_1 mesons. The restoration of chiral symmetry requires that the spectral function of the parity doublets e.g. ρ and A_1 mesons agrees in the symmetric phase. There are two simple scenario: a) the masses become the same, or b) their vacuum spectral functions mixes and the mixing is complete in the symmetric phase. We studied the second possibility. The mixing depends on the density. We derived the mixing parameter as a function of density from QCD sumrules.

We, furthermore, looked for experimental signature of this effect. Our suggestion is to find 3 pion decay of the ρ-meson, which is negligible in vacuum. On the other hand, this is the main hadronic decay channel of A_1, so as density increases it become more and more important for ρ-meson as well. Since pions are strongly interacting particles they suffer strong final state interaction which may make the observation of the 3 pions from the decaying A_1 very difficult. We have to find a ρ-peak in the 3 pion invariant mass spectrum. We sugggest to observe it in π-C collisions at around 1.3-1.5 Gev (SIS energy range). In pion induced reactions the pions carrying the signal has much higher probability to escape without further interaction. Choosing C for the target has the same reason. Although at Au target the available density is much larger and so the A_1 production has a much higher cross section compared to C target, but as the calculations show the signal (undisturbed 3π from A_1) to background ratio is highest at C target.

We studied this with a transport model which was very succesful to describe relativistic heavy ion collisions. To prepare for that job, we had to improve our model to describe the 3 pion background better. We refitted the collision term of our transport model. We added the experimental 3 pion final states to our fit. The new model describes the pion and proton induced reactions to 1pi, 2pi, 3pi, K, eta, sigma, rho and omega creations rather well. (Up to now the usually transport models are not controlled by the 3pi channels.)

Now it seems that we found an experimentally detectable signal, by using combinatorial background subtractions. We showed, that although the signal to background ratio is 0.01 at best, after subtraction there remains a rho-peak. The effect is still at the border of detectability, and we still look for some region in the phase space, where this effect is stronger.

We presented this work in several conferences, published [8, 9] and we submitted a paper about this work to International Journal of Modern Physics E.

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