Final Report

1 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 [8]. 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.

To study medium effects of vector mesons in the dilepton spectra we used another model, a BUU. Here in a resonance model all the production channels were coupled and fitted together to the experimental scattering data. 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 [9].

We studied that problem even further. We 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. We showed that our approach is energy-momentum conserving and in vacuum particles regain their vacuum properties. This model could also describe the HADES data. Unfortunatelly, even strong modification of vector mesons will be washed out in the final dilepton spectrum [10].

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 $pp \to ppe^+e^-$ [3] 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.

2 Strange particle production

We calculated kaon and ϕ-meson production in heavy ion collisions with our BUU and could describe the experimental FOPI data very well [4].

Since in different transport models there are large differences for kaon production we compared all the relevant transport codes at SIS energies, and calculated the kaon production [2].

3 omega and rho in matter

At the beginning of the supported period, we finished our work with german colleagues on the properties of rho and omega mesons in nuclear matter [1, 7]. We built a unitary model where we fitted the coupling constants to the available experimental scattering data. We found that the properties of omega are rather robust to the details of the model. In dense matter the spectral function of the omega has two-peak structure. On the other hand, the in-medium behaviour of the rho meson is strongly model dependent. We also calculated that scattering length of the mesons: eta, rho, omega and agreed with other models calculations.

4 $\rho - A_1$-mixing in matter

We continued that direction with T. Hatsuda by studying 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 [5, 6] and we submitted a paper about this work to International Journal of Modern Physics E.

5 pentaquark

In 2003-2004 a number of experiments announced the observation of a hypothetical pentaquark hadron state. We contributed to the phenomenological background of these experiments by studying the angular distribution of those particles created in proton-proton collisions.

6 Freeze out

We study ultrarelativistic heavy ion collisions using a three dimensional numerical hydrodynamical model. We currently work on the description of the hadronization and freeze out processes during which the experimentally observed final state particles are created. Such a model is essential because they provide a way of extracting experimentally observable quantities from numerical hydrodynamic calculations which only give a valid description of the quark gluon plasma phase of the reaction.

We use a description of the freeze out and hadronization processes which takes into account the experimental findings that the elliptic flow of hadrons produced in ultrarelativistic heavy ion collisions scales with the number of constituent quarks in the hadron. According to theoretical studies this can be a sign of the dominance of recombination processes during hadronization.

We developed computer codes implementing this description of the freeze out process. This work is in the stage of adjusting some free parameters of the model in order to get realistic predictions for observables comparable to experiment. We plan two publications in the near future: one about the theoretical framework that is used in the model and one about actual numerical calculations.

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