

RESONANCE PRODUCTION IN A THERMAL MODEL* **

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We discuss the $\pi^+\pi^-$ invariant-mass correlations and the resonance production in a thermal model with single freeze-out. The predictions are confronted with the recent data from the STAR Collaboration.

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Detection of hadronic resonances at RHIC (see the contribution of Fa-chini and Refs. [1, 2]) provides important clues on the particle production mechanism and subsequent evolution of the system formed at mid-rapidity in relativistic heavy-ion collisions. In this talk we analyze the $\pi^+\pi^-$ invariant-mass correlations in the framework of the single-freeze-out model of Ref. [3]. For more details the reader is referred to Ref. [4].

The thermal statistical approach to heavy-ion physics has been very instructive and successful in classifying and understanding the data (*cf.* contributions of Gaździcki p. 187, Ster p. 191, and Becattini p. 207). We recall briefly the basic assumptions of our model:

1. An approximation of a single freeze-out, $T_{\text{chem}} = T_{\text{kin}} \equiv T$, is made. This has recently gathered experimental support, with the short lifetime of the hadronic phase obtained from the HBT measurements of $R_{\text{out}}/R_{\text{side}} \sim 1$ and from the out-of-plane elongation of R_{side} (*cf.* contributions of Appelshäuser and Lisa).

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2. A *complete* treatment of resonances, with all light-flavor particles from the Particle Data Tables incorporated.
3. The shape of the freeze-out hypersurface is assumed in the spirit of the Buda–Lund model [5]. It possesses a Hubble-like flow, with the four-velocity proportional to the coordinate, $u^\mu = x^\mu/\tau$.
4. The model has altogether four parameters. The thermal ones, $T = 160$ MeV and $\mu_B = 26$ MeV at $\sqrt{s_{NN}} = 200$ GeV, are fixed by fitting the ratios of the particle abundances. The geometry parameters, namely the invariant time at freeze-out τ , which controls the overall normalization, and the transverse size ρ_{\max} are fixed by fitting the p_\perp spectra.

In order to analyze the $\pi^+\pi^-$ invariant mass spectra measured in Ref. [2] with the like-sign subtraction technique, we make the assumption that all the correlated pion pairs are obtained from the decays of neutral resonances: ρ , K_S^0 , ω , η , η' , f_0/σ , and f_2 . The phase-shift formula for the volume density of resonances with spin degeneracy g is given by the formula [6]

$$\frac{dn}{dM} = g \int \frac{d^3p}{(2\pi)^3} \frac{d\delta_{\pi\pi}(M)}{\pi dM} \frac{1}{\exp\left(\frac{\sqrt{M^2 + \mathbf{p}^2}}{T}\right) \pm 1}, \quad (1)$$

and was used in Ref. [4]. We note that the same formalism has been also applied by Pratt and Bauer [7] in a similar analysis. In some works the spectral function of the resonance is used as the weight, instead of the derivative of the phase shift. For narrow resonances this does not make a difference, since then $d\delta(M)/dM \simeq \pi\delta(M - m_R)$. For wide resonances, such as in the scalar–isoscalar channel, or for effects of tails, the difference between the correct formula and the one with the spectral function is significant.

In order to get a feeling on the problem, we first carry on a warm-up calculation, where a static source is used. Fig. 1 shows the mid-rapidity invariant-mass spectra computed at two different values of the freeze-out temperature: $T = 165$ MeV and 110 MeV. We note a clear appearance of the included resonances, as well as a feature of a much steeper fall-off of the strength in Fig. 1(b), which simply reflects the lower value of the temperature. Thus, the $\pi^+\pi^-$ invariant-mass spectrum provides yet another *thermometer* for the decoupling temperature.

The collective flow has no effect on the invariant mass of a pair of particles produced in a resonance decay, since the quantity is Lorentz-invariant. Nevertheless, it affects the measured results since the kinematic cuts in an obvious manner break this invariance. We have performed a full-fledged

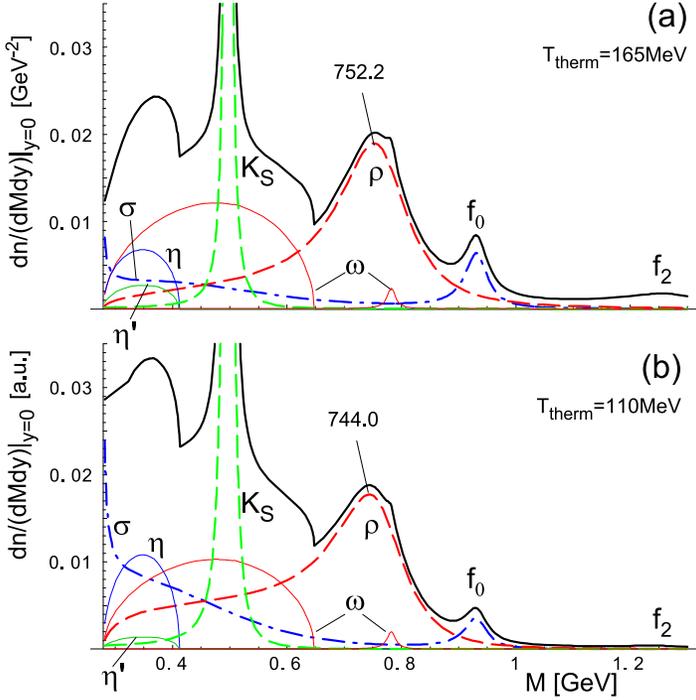


Fig. 1. Calculation of the $\pi^+\pi^-$ invariant-mass correlation from decays of resonances in a thermal model with a static source. (a) The case of $T_{\text{therm}} = T_{\text{chem}} = 165 \text{ MeV}$. (b) The case of $T_{\text{therm}} = 110 \text{ MeV}$. The numbers indicate the position of the ρ peak (in MeV) and the labels indicate the decay channel.

calculation in our model, including the flow, kinematic cuts, and decays of higher resonances. The results are shown in Ref. [4]. One of the thrilling aspects of the analysis is whether the observed shift of the ρ peak can be explained. We have found that the thermal effects and the kinematic cuts are able to shift it down by about 30 MeV, leaving a few tens of MeV unexplained. For that reason, we have repeated the calculation with the position of the ρ peak moved down by 9%. In Fig. 2 we compare the model predictions to the STAR data. Our results were scaled by a common factor, which is equivalent to fitting the value of τ for the peripheral collisions of the STAR experiment. Then they were filtered by the detector efficiency correction (we are grateful here to Patricia Fachini). We note that the model does a very good job in reproducing the gross features of the data. We also note that the full model, with feeding from higher resonances and with flow/cuts, which has $T = 165 \text{ MeV}$, gives similar predictions to the naive model at $T = 110 \text{ MeV}$ rather than 165 MeV. This is yet another manifestation of the effect of “cooling” induced by the resonances [8].

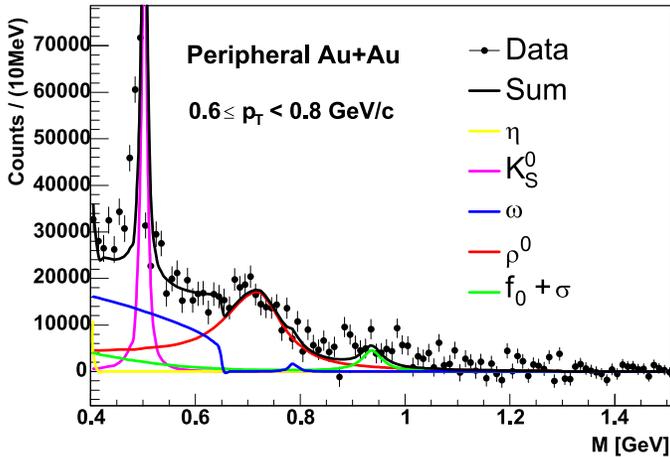


Fig. 2. Single-freeze-out model *vs* the data of Ref. [2] for the $\pi^+\pi^-$ invariant-mass correlations (from <http://www.star.bnl.gov/~pfachini/KrakowModel>). The model calculation includes the decays of higher resonances, the flow, the kinematic cuts, and the detector efficiency.

More details and further results and discussion concerning the abundances and the transverse-momentum spectra of various resonances can be found in Ref. [4].

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