

Thermal description of hadron production in e^+e^- collisions revisited

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The analysis of hadron yields measured in central heavy ion collisions from AGS up to RHIC energies has shown [1] that hadron multiplicities can be described very well with a hadro-chemical equilibrium approach. The natural question arising here is whether this statistical behavior is a unique feature of high energy nucleus-nucleus collisions or whether it is also applicable in elementary collisions like, e.g., e^+e^- .

Usually a 5-flavor jet approach is used for the fits on multiplicities in e^+e^- collisions [4], with the fractions of the quark flavors in hadronic events [3] as external input values, unrelated with the thermal model. We have adopted this approach in our study, but we have also considered a purely thermal scenario in which the presence of the heavy-quark jets is neglected [2]. We are using the latest multiplicity measurements summarized and published by the Particle Data Group (PDG) [3]. Since the aim is a precision calculation for a small system we employ a fully canonical form of the statistical model conserving baryon number N , charge Q , strangeness S , charmness C , and bottomness B . To reach within the model a precision comparable to that of the data from the LEP collider (a few percent), we have performed computations including quantum statistics.

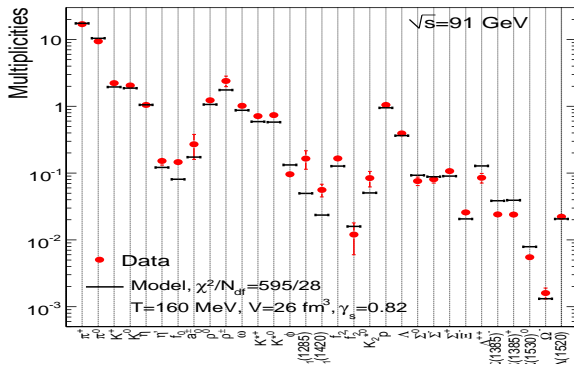


Figure 1: Thermal fit to hadron yields at the energy of 91 GeV.

The resulting best fit to the data at the energy $\sqrt{s}=91$ GeV is shown in Fig. 1 for the purely thermal scenario. We first note the overall behavior of the data, namely an approximately exponential decrease of particle yield with increasing particle mass. Such a behavior is expected in the hadron resonance gas model due to the Boltzmann factors, thus indicating the presence of statistical features of hadron production in elementary collisions. Clearly, the fit favors a strangeness suppression factor γ_s different than unity, at variance to the case in heavy-ion collisions.

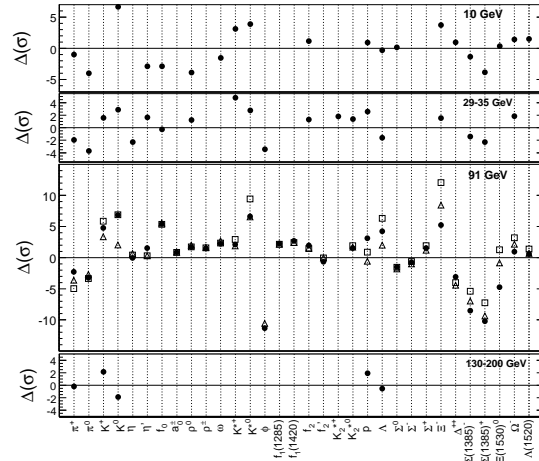


Figure 2: Difference (in units of experimental error) between experimental data and thermal model fits at four energies.

The quantitative description of the data with the statistical model is, however, rather poor and no improvement is visible for the case of subtracting charm and bottom contributions. The poor fit quality which is already visible in Fig. 1 becomes striking when, as in Fig. 2, we show for the four energies the difference Δ (in units of the experimental error) between the experimental data and the statistical model calculations for the best fit values. Typical χ^2 values per degree of freedom lie between 5 and 20 and discrepancies between single data points and fit values larger than 5 standard deviations are not rare. In particular, for all energies the yields of ϕ mesons and of hyperons are poorly reproduced. Large deviations are seen also for kaons. The case of the fit after subtraction of the contribution of the decays of charmed and bottom hadrons, explored at $\sqrt{s}=91$ GeV (open squares in Fig. 2), is characterized by a larger χ^2 value compared to the overall fit. The extracted fit parameters differ somewhat in the two cases. A third fit scenario, namely using a 5-flavor approach, shown by the triangles in Fig. 2, gives the lowest χ^2 value, although the value is still far from that of a good fit.

References

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