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Statistical thermal model analysis of particle production at LHC

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Statistical thermal model analysis of particle production at LHC

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Abstract. A successful description of the particle ratios measured in heavy-ion collisions has been achieved in the framework of thermal models. In such a way, a large number of observables can be reproduced with a small number of parameters, namely the temperature, baryo-chemical potential and a factor measuring the degree of strangeness saturation. The comparison of experimental data at and the model estimations has made possible to define the thermodynamic parameters of strongly interacting matter at chemical freeze-out temperature. The detailed study of hadron and meson production including resonances using the statistical-thermal model is discussed. Their ratios are compared with the existing experimental data and predictions are made for pp and heavy-ion collisions at RHIC and LHC energies.

1. Introduction

The statistical-thermal model has been proved successful in applications to relativistic collisions of both heavy ions and elementary particles. The achievement of this approach has pioneered to the design of various software codes [1-2]. THERMUS [3], a thermal model analysis package, has been developed for incorporation into the object-oriented ROOT framework.

THERMUS is able to make calculations within three statistical ensembles; grand-canonical ensemble which allows to fluctuate the conserved quantum numbers -Baryon (B), Strangeness (S) and Charge (Q)- on average; a canonical ensemble imposing all the quantum numbers to be conserved exactly and finally a mixed or strangeness canonical ensemble which is a combination of the canonical treatment of strangeness and grand canonical treatment of quantum number B and Q.

2. Analysis

In order to calculate the thermal properties of a system, one starts with an evaluation of its partition function. The form of the partition function obviously depends on the choice of ensemble. THERMUS is able to make calculations within three statistical ensembles; the grand canonical ensemble (GCE), the canonical ensemble (CE) and the strangeness canonical ensemble (SCE), respectively.

In all ensemble THERMUS use the different parameters:

Table 1. Parameters used in various canonical ensembles.

GCE	CE	SCE
$T, \mu_B, \mu_S, \mu_Q, \mu_C, \gamma_S, \gamma_C, R$	T, B, S, Q, γ_S, R	$T, \mu_B, \mu_Q, \gamma_S, R_C, R$

T presents the temperature of the systems, μ_B, μ_S and μ_Q are the baryon, strangeness and charge chemical potentials. γ_S is strangeness saturation factor, γ_C is charm saturation factor and R is the radius of the fireball, *B, S* and *Q* are baryon, strangeness and charge quantum numbers, R_C is the correlation or the canonical radius, respectively.

The STAR detector [5], one of the experiments at Relativistic Heavy Ion Collider (RHIC), primarily designed to study the formation of quark–gluon plasma (QGP). In this proceeding, STAR pp, dAu and AuAu collisions at the energy of 200 GeV are discussed.

Figure 1(a) shows the comparison of STAR data in pp collisions at $\sqrt{s} = 200$ GeV and THERMUS results. CE is preferred since there is poor particle production in the given collision system. The analysis of STAR data from dAu collisions at $\sqrt{s_{NN}} = 200$ GeV and the particle ratios from the STAR AuAu data at $\sqrt{s_{NN}} = 200$ GeV are given in figure 1(b) and figure 1(c), respectively. In all figures, the solid lines show the THERMUS predictions while closed circles refer to the experimental data.

In figure 1(a), CE is preferred since there is a poor particle production in the given collision system. The fit parameter we obtain for the radius of the fireball (R), is 4.14 ± 0.43 fm, and also the quantum numbers B and Q are equal to 2 while S is fixed to 0. In figure 1(b), the radius of the fireball fixed to 7 fm in both GCE and the SCE analysis while some of the thermal model parameters are listed as: $\mu_S = 0.1 \pm 0.6$ MeV, $\mu_Q = 5 \pm 1.6$ MeV for GCE analysis, $\mu_Q = 3 \pm 2.8$ MeV, $R_C = 5.28 \pm 1.35$ fm for SCE analysis. Also in figure 1(c), two different ensembles are compared while R is fixed to 10 fm. Some fit parameters taken from GCE analysis are $\mu_S = 5.2 \pm 3.5$ MeV, $\mu_Q = -1.9 \pm 3.1$ MeV and ones from SCE analysis are as follows: $\mu_Q = -1.9 \pm 3.8$ MeV, $R_C = 2 \pm 2.3$ fm.

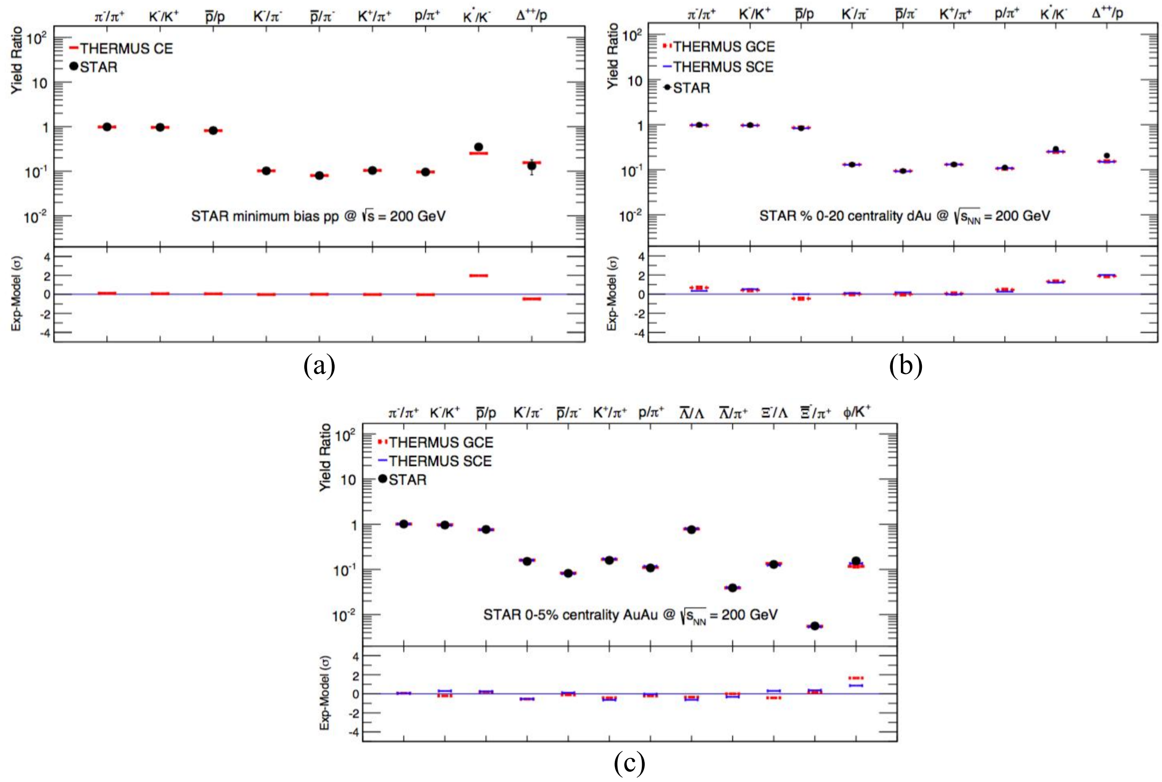
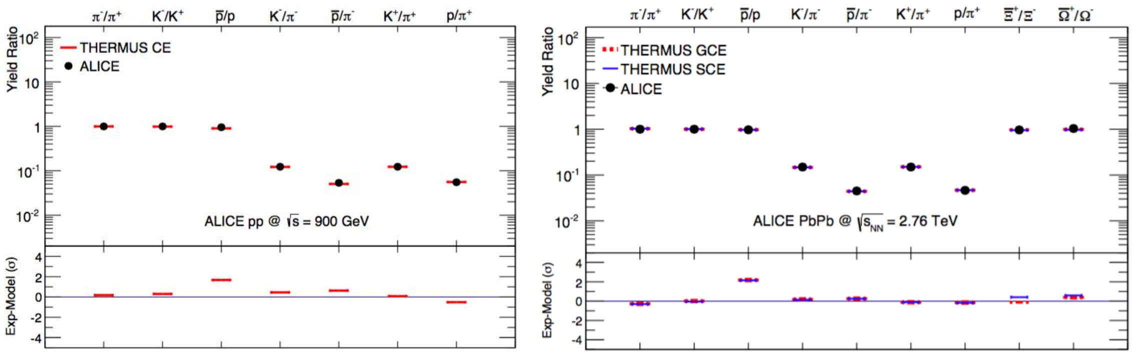


Figure 1. Comparison of STAR data and THERMUS results [4]

The ALICE detector [6] in The Large Hadron Collider (LHC) is also designed to engage the QGP formation and its physical processes. In this analysis, the experimental data from both elementary particles and heavy-ion collisions are included.



(a) (b)

Figure 2. Comparison of ALICE data and THERMUS results [4]

In figure 2(a) shows the comparison of ALICE data in pp collisions at $\sqrt{s} = 900$ GeV and THERMUS results and comparison of ALICE data in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and THERMUS results are given in figure 2(b).

The radius R is extracted as 8 ± 0.2 fm and the quantum numbers B and Q are fixed to 2 and S equals to 0 as well in figure 2(a). In figure 2(b), the analysis is achieved by using two ensembles while R fixed to 10 fm. The model parameters extracted by the GCE are $\mu_S = 2.3 \pm 0.8$ MeV and $\mu_Q = -2.7 \pm 0.8$ MeV whereas the ones coming from SCE analysis are: $\mu_Q = -2.7 \pm 0.8$ MeV and $R_C = 3.38 \pm 3.21$ fm.

3. Results and Conclusions

Both the STAR and the ALICE data together with their THERMUS predictions and the temperature dependencies of statistical thermal parameters are studied. The canonical ensemble is used for pp system, and SCE is implemented for not only pp system at higher energies but also for dAu and PbPb systems. Finally, GCE is chosen for AuAu and PbPb collisions and some cases for dAu system. In this study is the first one give predictions for the STAR data in pp, dAu and AuAu collisions at the energy of 200 GeV and also ALICE data in pp system at $\sqrt{s} = 900$ GeV and PbPb system at $\sqrt{s_{NN}} = 2.76$ TeV are successfully reproduced by a thermal model.

In the analysis presented in this proceeding, the statistical-thermal parameters are determined at the chemical freeze-out point which gives information about the QGP medium. The parameters, $T_{ch} = 166 \pm 3.8$ MeV and $T_{ch} = 173 \pm 5.8$ MeV are extracted from the analysis of STAR data in dAu collisions and in AuAu collisions at the energy of 200 GeV, respectively. Also, $T_{ch} = 146 \pm 4$ MeV is from the analysis of ALICE data in pp collisions at $\sqrt{s} = 900$ GeV and $T_{ch} = 163 \pm 0.5$ MeV is from the analysis of ALICE data in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV have been extracted.

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