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Transverse energy and charged-particle multiplicity at various centralities at RHIC: Statistical model estimates[⋆]

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Abstract. The transverse energy and the charged-particle multiplicity at midrapidity are evaluated in a single-freeze-out model for different centrality bins at RHIC at $\sqrt{s_{NN}} = 130$ and 200 GeV. The predictions of the model are done at the freeze-out parameters determined earlier from measured particle yields and p_T spectra. The results agree qualitatively well with the experimental data.

PACS. 25.75.-q Relativistic heavy-ion collisions – 25.75.Dw Particle and resonance production – 24.10.Pa Thermal and statistical models

The statistical model has succeeded in the description of the soft part of particle production in heavy-ion collisions [1]. In particular, particle yield ratios and p_T spectra of identified hadrons have been reproduced with a good accuracy. Transverse energy ($\mathrm{d}E_T/\mathrm{d}\eta$) and charged-particle multiplicity densities ($\mathrm{d}N_{ch}/\mathrm{d}\eta$) are global variables whose measurements are independent of hadron spectroscopy, therefore they could be used as an additional test of the self-consistency of the statistical model.

The experimentally measured transverse energy is defined as

$$E_T = \sum_{i=1}^{L} \hat{E}_i \cdot \sin\theta_i \ , \qquad (1)$$

where θ_i is the polar angle, $\hat{E}_i$ denotes $E_i - m_N$ (m_N means the nucleon mass) for baryons, $E_i + m_N$ for antibaryons and the total energy E_i for all other particles and the sum is taken over all L emitted particles [2].

The statistical model with single freeze-out [3,4] is applied for evaluations of $\mathrm{d}E_T/\mathrm{d}\eta$ and $\mathrm{d}N_{ch}/\mathrm{d}\eta$ at midrapidity for various centrality bins at RHIC at $\sqrt{s_{NN}} = 130$ and 200 GeV. Details of this analysis can be found elsewhere [5,6]. The foundations of the model are as follows: a) the chemical and thermal freeze-outs take place simultaneously, b) all confirmed resonances up to a mass of 2 GeV from the Particle Data Tables [7] are taken into account, c) a freeze-out hypersurface is defined by the equation $\tau = (t^2 - r_x^2 - r_y^2 - r_z^2)^{1/2} = \mathrm{const}$, d) the four-velocity of an element of the freeze-out hypersurface is proportional to its coordinate, $u^\mu = x^\mu/\tau$, e) the transverse size is restricted by the condition $r = (r_x^2 + r_y^2)^{1/2} < \rho_{max}$. The model has four parameters, namely, the two thermal parameters, the temperature T and the baryon number chemical potential μ_B, and the two geometric parameters, τ and ρ_{max}. Values of these parameters were obtained from fits to particle yield ratios and p_T spectra (see table 1 in [6], the table collects the results from [4,8]). The invariant distribution of the measured particles of species i has the Cooper-Frye form [3,4]. The distribution collects, besides the thermal one, also contributions from simple and sequential decays such that at least one of the final secondaries is of the i kind (for details, see [4,5]). Having integrated this distribution suitably over p_T and summing up over final particles, one can obtain $\mathrm{d}E_T/\mathrm{d}\eta$ and $\mathrm{d}N_{ch}/\mathrm{d}\eta$ and finally the ratio $\langle \mathrm{d}E_T/\mathrm{d}\eta\rangle/\langle \mathrm{d}N_{ch}/\mathrm{d}\eta\rangle$. The complete set of results for $\mathrm{d}E_T/\mathrm{d}\eta$ and $\mathrm{d}N_{ch}/\mathrm{d}\eta$ can be found in [6], here only the values of the ratio as a function of the number of participants (N_{part}) are shown in figs. 1 and 2.

As one can see, the position of model predictions is very regular and exactly resembles the configuration of the data in each case, the estimates are only shifted up about 10% as a whole. This overestimation can be explained, at least for more central collisions, by the observed discrepancy between the directly measured $\mathrm{d}N_{ch}/\mathrm{d}\eta$ and $\mathrm{d}N_{ch}/\mathrm{d}\eta$ expressed as the sum of the integrated charged-hadron yields (this effect was notified in backup slides of [9]). If the original data points are replaced by the recalculated data such that the denominators are sums of the integrated charged-hadron yields, then much better agreement can be reached for more central collisions.

As far as the predictions for $\mathrm{d}E_T/\mathrm{d}\eta$ and $\mathrm{d}N_{ch}/\mathrm{d}\eta$ are concerned (see figs. 1-4 in [6]), the agreement with the data is much better for RHIC at $\sqrt{s_{NN}} = 130$ GeV. For

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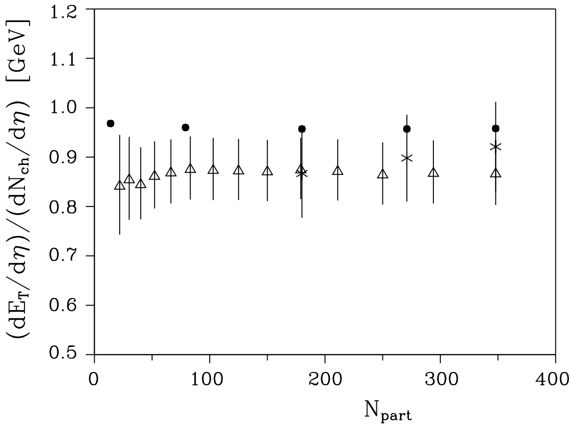

Fig. 1. $\langle dE_T/d\eta\rangle/\langle dN_{ch}/d\eta\rangle$ *versus* N_{part} for RHIC at $\sqrt{s_{NN}} = 130\,\text{GeV}$. Dots denote model evaluations, triangles are the PHENIX data [2]. Crosses denote recalculated PHENIX data points, *i.e.* the sum of integrated charged-hadron yields [10] have been substituted for the denominator in the ratio.

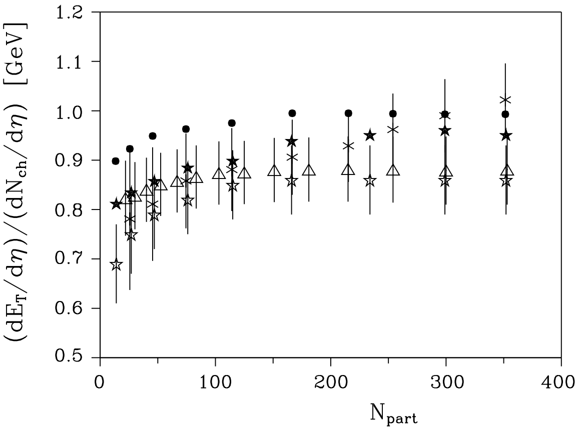

Fig. 2. $\langle dE_T/d\eta\rangle/\langle dN_{ch}/d\eta\rangle$ *versus* N_{part} for RHIC at $\sqrt{s_{NN}} = 200\,\text{GeV}$. Black dots and stars are model evaluations for PHENIX and STAR, respectively. Triangles are the direct PHENIX data [2], whereas crosses are recalculated PHENIX data points, *i.e.* the sum of integrated charged-hadron yields [11] have been substituted for the denominator in the ratio. Open stars are the STAR data [12].

the case of $\sqrt{s_{NN}} = 200\,\text{GeV}$, only a rough qualitative agreement has been reached. For sure, one of the reasons is that fits in [8] were done to the preliminary data for the spectra [9,13] and, as it turned out later, the final data [11, 14] differ substantially from the preliminary ones.

To conclude, the single-freeze-out model fairly well explains the observed centrality dependence of transverse energy and charged-particle multiplicity pseudo-rapidity densities at midrapidity and their ratio in the case of RHIC collisions at $\sqrt{s_{NN}} = 130$ and $200\,\text{GeV}$. These two variables are independent observables, which means that they are measured independently of identified hadron spectroscopy. It should be stressed once more that the model fits were done earlier with the use of particle yield ratios and p_T spectra (not by the author, values of fitted parameters are taken from [4,8]). With the values of parameters given, transverse energy and charged-particle multiplicity densities have been calculated in the single-freeze-out model. Generally, the results agree qualitatively well with the data. This adds a new argument supporting the idea of the appearance of a thermal system during an ultra-relativistic heavy-ion collision.

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References

1. For some reviews, see A. Bialas, Nucl. Phys. A **715**, 95 (2003); P. Braun-Munzinger, K. Redlich, J. Stachel, in *Quark Gluon Plasma 3*, edited by R.C. Hwa, X.-N. Wang (World Scientific, 2004) p. 491; P.F. Kolb, U.W. Heinz, in *Quark Gluon Plasma 3*, edited by R.C. Hwa, X.-N. Wang (World Scientific, 2004) p. 634 and references quoted there.
2. PHENIX Collaboration (S.S. Adler *et al.*), Phys. Rev. C **71**, 034908 (2005).
3. W. Broniowski, W. Florkowski, Phys. Rev. Lett. **87**, 272302 (2001); Phys. Rev. C **65**, 064905 (2002).
4. W. Broniowski, A. Baran, W. Florkowski, Acta Phys. Pol. B **33**, 4235 (2002).
5. D. Prorok, Eur. Phys. J. A **24**, 93 (2005).
6. D. Prorok, Eur. Phys. J. A **26**, 277 (2005) hep-ph/0412358.
7. Particle Data Group Collaboration (K. Hagiwara *et al.*), Phys. Rev. D **66**, 010001 (2002).
8. A. Baran, W. Broniowski, W. Florkowski, Acta Phys. Pol. B **35**, 779 (2004).
9. PHENIX Collaboration (T. Chujo), Nucl. Phys. A **715**, 151 (2003); `http://alice-france.in2p3.fr/qm2002/Transparencies/20Plenary/Chujo.ppt`.
10. PHENIX Collaboration (K. Adcox *et al.*), Phys. Rev. Lett. **88**, 242301 (2002).
11. PHENIX Collaboration (S.S. Adler *et al.*), Phys. Rev. C **69**, 034909 (2004).
12. STAR Collaboration (J. Adams *et al.*), Phys. Rev. C **70**, 054907 (2004).
13. STAR Collaboration (O. Barannikova, F. Wang), Nucl. Phys. A **715**, 458 (2003).
14. STAR Collaboration (J. Adams *et al.*), Phys. Rev. Lett. **92**, 112301 (2004).