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Transverse momentum distributions of Charm Mesons in Relativistic Heavy-Ions Collisions studied through Non-Extensive Statistics

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This work aims the application of non-extensive statistics, more specifically that proposed by C. Tsallis [1], in the study of the transverse momentum distribution of hadrons composed of charm quarks produced in collisions between heavy ions at relativistic energies. Non-extensive statistics has been very successful in the description of transverse momentum spectra of particles produced in hadronic collisions at high energies and the interpretation of the non-extensive parameter q has been widely discussed. The success of this description might be connected to the degree of equilibrium reached in these collisions, an important condition for a broad understanding of its dynamics. This question is particularly important for heavy quarks in collisions between heavy ions, given its unique role in the investigation of the medium formed in these collisions.

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1. Model and Results

As heavy-ion collision systems are expected to undergo a hydrodynamic expansion, we have used the Tsallis statistics embedded in a Blast-Wave model. The equation used in this work was taken from [2],

$$\frac{d^2N}{2\pi p_T dp_T dy} \propto m_T \int_{-y_b}^{y_b} \cosh(y_s) dy_s \int_{-\pi}^{\pi} d\phi \int_0^R r\, dr \left(1 + \frac{q-1}{T}\left(m_T \cosh(y_s)\cosh(\rho) - p_T \sinh(\rho)\cos(\phi)\right)\right)^{\frac{-1}{q-1}} \quad (1)$$

In the expression, y and $y_b = \ln\left(\sqrt{s}/m_N\right)$ are the rapidities of the produced particle and the colliding beam, respectively; m_N is the mass of the colliding nucleon and $m_T = \sqrt{m^2 + p_T^2}$ is the transverse mass. The integration variables are y_s, the rapidity of the particle's emitting source, ϕ, the azimuthal angle perpendicular to the beam direction, and r, the distance to the center of the fireball. $\rho = \text{arctanh}\left(\beta_s \ (r/R)^n\right)$ is the expansion rapidity of the fireball, β_s being the expansion velocity at its surface. We have studied both constant (n = 0) and linear (n = 1) velocity profiles.

The distribution in (1) was fitted to the transverse momenta spectra of charmed particles in Pb-Pb collisions at 5.02 TeV and pp collisions at 13 TeV. Table 1 shows the data that was used to perform the fits, extracted from references from [3–7]. Three centrality classes of Pb-Pb collisions at 5.02 TeV were used and three different multiplicity classes of pp collisions at 13 TeV were also included for comparison purposes.

Since the data represent the average number of particles on each bin of transverse-momentum, we have fitted averages of the TBW function over the measured bins of p_T to the data, using a least-χ^2 method. The parameters q, T and $\langle\beta\rangle$ were common for all particles, and each spectrum had a separate normalization constant. The minimizations were performed using the TMinuit class in ROOT [8]. In the fits, we have used as uncertainty the square-root of the sum of the squares of the statistical and systematic uncertainties of the data. The fits obtained have a very good quality.

Figure 1 shows the values of the parameters obtained from the fits as a function of $\langle dN_{ch}/d\eta\rangle$, with values taken from [11, 12] for each studies class of centrality or pp collision multiplicity bin. In these figures, besides the fits to heavy hadrons performed in this work, we have also included the results of fits to lighter particles spectra (π, K, p, K^{*0}, ϕ) performed in [9, 10]. We have found that the q value tends smoothly to unity as the multiplicity increases matching the behavior of pp and Pb-Pb collisions. An interesting observation from this work is the fact that the heavy hadrons follow the same trend as the light ones, but with q values higher for heavy hadrons. The values for $\langle\beta\rangle$ increase with multiplicity but have smaller values for heavy hadrons.

Table 1: References for the spectra analysed.

Colliding System	Spectra	Cent./Mult. Class	Reference
Pb-Pb 5.02 TeV	D^0, D^+, D^{*+}	0-10%, 30-50%	[3]
Pb-Pb 5.02 TeV	D_s^+	0-10%, 30-50%	[4]
Pb-Pb 5.02 TeV	Λ_c	0-10%, 30-50%	[5]
Pb-Pb 5.02 TeV	D^0, D^+, D^{*+}, D_s^+	60-80%	[6]
pp 13 TeV	D^0, D_s^+	V0M I, II, III	[7]

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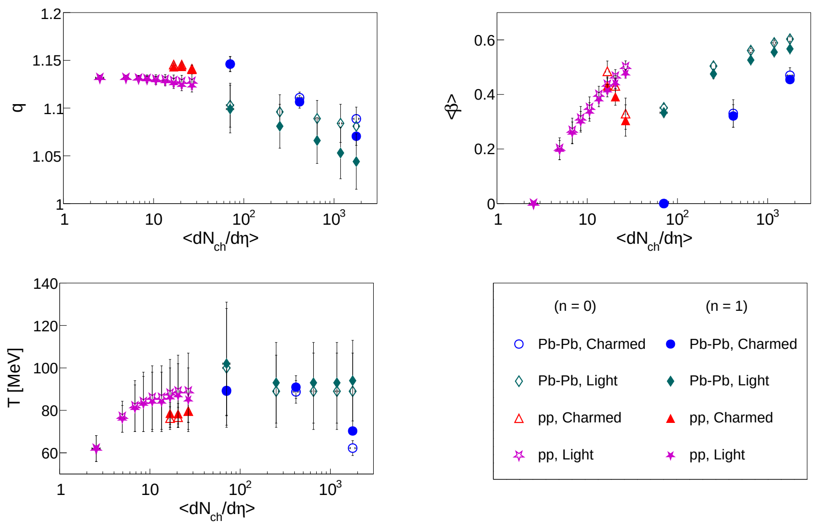

Figure 1: TBW parameters as a function of the average multiplicity of charged particles. The colliding systems studied are Pb-Pb 5.02 TeV and pp 13 TeV. The data for the light particles was taken from [9, 10].

2. Conclusion

We presented some results of a systematic study of charmed hadrons transverse momentum distributions fits, mainly the relative behavior of the non-extensive parameter q for different particles and collision centralities. The purpose of this study is to investigate whether this approach can give hints regarding the dynamics of charm quarks in these collisions. The next step of this work is to seek for an understanding of the behavior of these parameters, which are sensitive to the different dynamics of heavy quarks (charm, in this case) in the medium formed in collisions between heavy ions when compared to other particles.

References

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