“Estimation of the temperature of the nuclear matter from the V0 cross sections in p-p and p-Pb collisions in LHCb experiment at $\sqrt{s_{NN}} = 5.02$ TeV”

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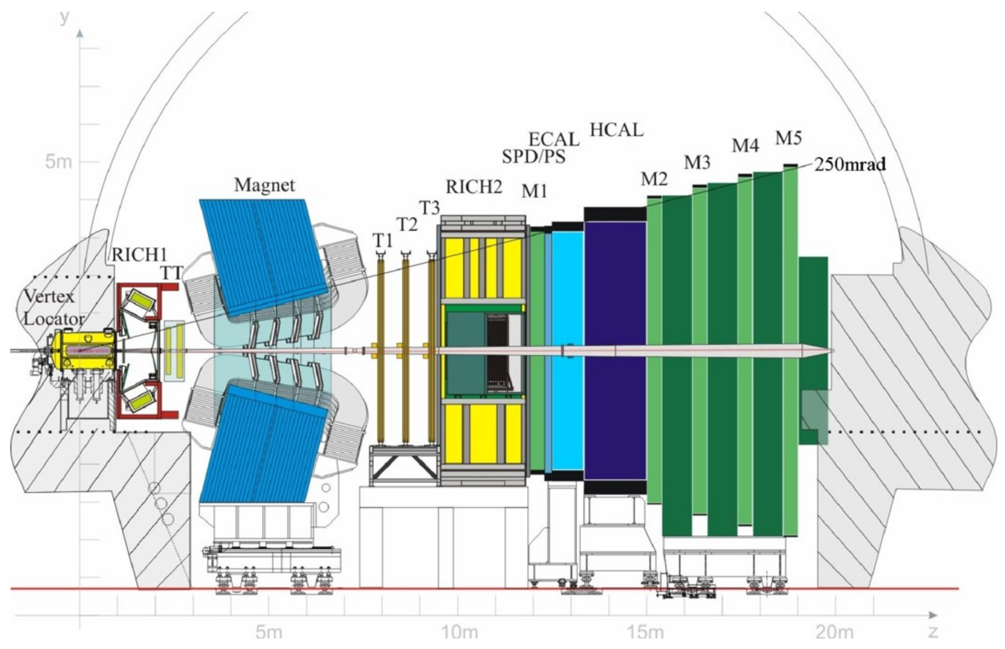
Motivation

The study of hadron production in a strongly interacting environment is expected to shed light on the quest of the partial restoration of chiral symmetry in hot nuclear matter. A modification of hadron production features (differential cross-sections, mass and width, branching ratios etc.) has been predicted by the Quantum Chromodynamics models.

The strength of the modification depends on the baryon density and the temperature. To identify signatures of the Quark-Gluon-Plasma studies are undertaken to compare quarkonium production cross-sections measured in proton-proton, proton-nucleus and nucleus-nucleus collisions. Whilst the highest probability of QGP creation is expected in nucleus-nucleus collisions, one may assumed that the proton-nuclear reaction proceeds in cold nuclear matter with a well-defined density, thus revealing the Cold Nuclear Matter effects.

Do we can observe QGP in proton-proton and proton-nucleus collisions?

p-p??? p-Pb?? Pb-Pb?



Methods and data

The LHCb detector is a single-arm forward spectrometer covering the pseudorapidity range $2 < \eta < 5$, which have many advanced feature for precise particle`s transverse momentum measurement at high energies in all three types of collisions (nucleon-nucleon, nucleon—nucleus and nucleus-nucleus).

In this work analysis with V0 production cross-sections measured in p-p and p-Pb collisions with LHCb forward spectrometer at 5.02 TeV is mainly presented. Also ALICE data of V0 production for p-p collision at 0.9 and 7 TeV were used [1][2][3].

By using transverse momentum spectra of V0 particle and different thermodynamic models we can calculate temperature of the nuclear matter and compare it to theoretical predictions of QGP temperature.

Results

In this work to describe transverse momentum spectra various models were used such as : Maxwell–Boltzmann (1), Tsallis (2)[4], Levy (3)[1] and most common modifications of these distributions. These models used to describe transverse momentum spectra of K short mesons, Lambda and anti Lambda hyperons.

$$F_{M-B} = A p_T^2 \exp\left(-\frac{\sqrt{p_T^2+m_0^2}}{T}\right) (1),$$

$$F_{Tsallis} = A p_T \left(1+\frac{p_T}{T}\right)^{-n} (2),$$

$$F_{Levy} = A p_T \frac{(n-1)(n-2)}{nT(nT+m_0(n-2))}\left(1+\frac{\sqrt{p_T^2+m_0^2}-m_0}{nT}\right)^{-n} (3).$$

A - normalization constant, p_T - particle`s transverse momentum, m - particle`s mass, T - temperature.

A, T, q - are fitted parameters.

Among all distribution and modifications after primary fitting to LHCb and ALICE data by using next criteria (first - χ^2 criterion, second - temperature of the nuclear matter cannot be higher than QGD temperature [5], third - Λ temperature should be higher than K_s, fourth - temperature—energy dependence [6,7]) one distribution was selected as best fit model - modification of Tsallis distribution(F_{T6} on plots):

$$\chi2/NDF \approx 1,$$

$$T_\Lambda, T_{\bar{\Lambda}}, T_{K_S^0} \in (0-180]\ \mathrm{MeV}$$

$$T_{\bar{\Lambda}} \approx T_\Lambda > T_{K_S^0},$$

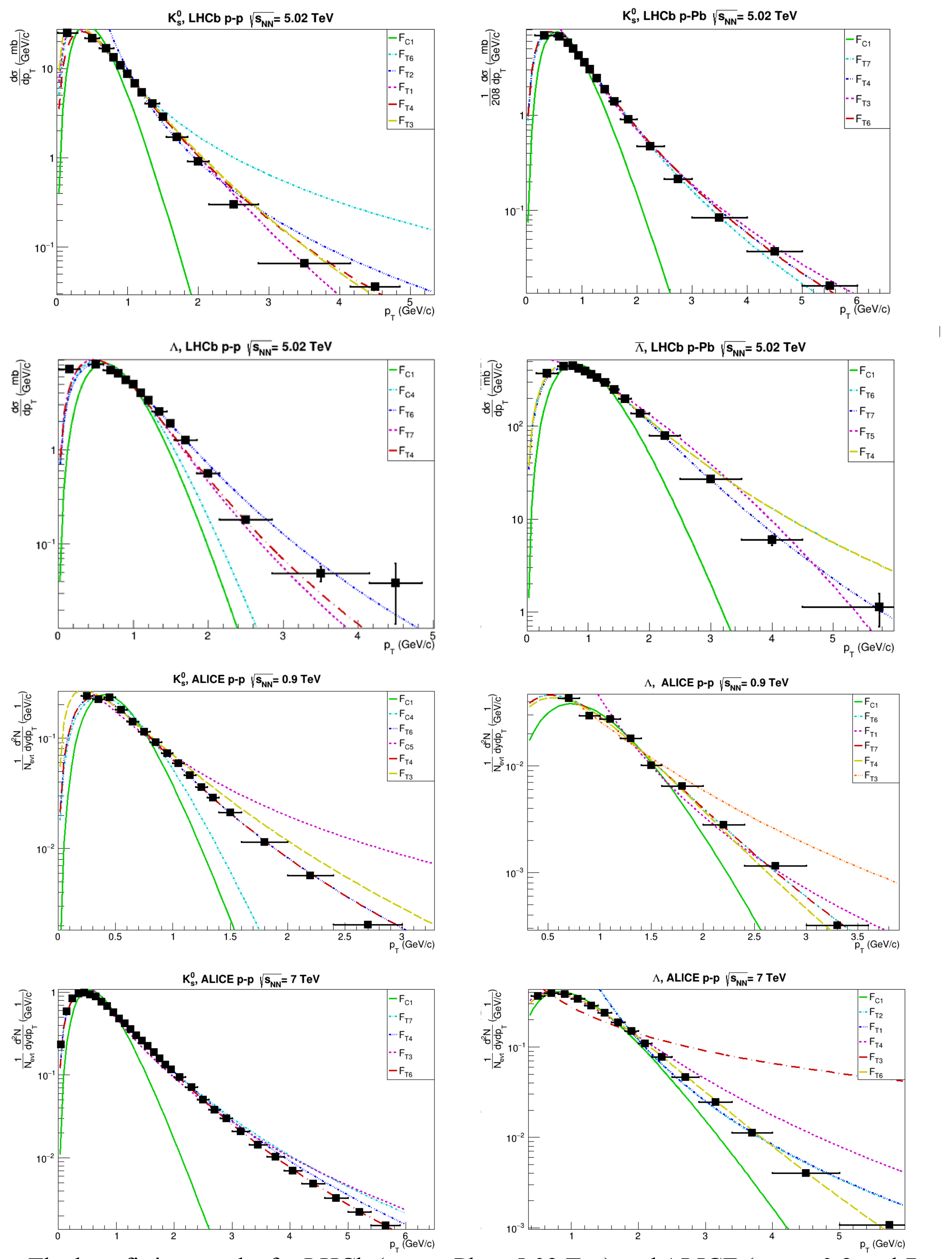
$$T(s_{NN}) = T_0 + T_1 \ln\left(\frac{\sqrt{s_{NN}}}{m_0}\right),$$

$$F_{T.Modify} = A p_T\left(1+n\frac{\sqrt{p_T^2+m_0^2}-m_0}{T}\right)^{-\frac{1}{n}}$$

Using $F_{T.Modify}$ we obtained the final temperature estimate for the cases of K_s , Λ and Λ^- in p-p and p-Pb collisions at $\sqrt{s_{NN}}$= 5.02 TeV in LHCb experiment.

The fitting results and estimated temperatures are shown in table below.

Collision	Particle	T [GeV]	ΔT [GeV]	χ^2/NDF(T)	T_1 [GeV]	Δ T_1[GeV]	χ^2/NDF(T_1)
pp	K_S^0	0.121	0.008	10.51/12	0.043	0.027	1.80/1
	Λ	0.150	0.015	2.97/12	0.057	0.027	1.85/1
	$\bar{\Lambda}$	0.148	0.016	5.76/12	_	_	_
pPb	K_S^0	0.147	0.022	6.72/13	_	_	_
	Λ	0.179	0.017	5.39/13	_	_	_
	$\bar{\Lambda}$	0.181	0.027	9.02/13	_	_	_



The best fitting results fot LHCb (p-p, p-Pb at 5.02 Tev) and ALICE (p-p at 0.9 and 7 TeV) data (F_C - modification of Maxwell–Boltzmann,F_T - modification of Tsallis, F_L - modification of Levy).

Conclusion and outlook

In this work were selected model that best described the experimental data and gave values closest to the theoretical prediction, the dependence of temperature on $\sqrt{s_{NN}}$ and the type of collision was investigated.

Further plans to work on this topic include the study of other thermodynamic models and carrying out the analysis for V0 particles production in p-Pb collisions at 8 TeV.

Reference

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[2] arXiv:1307.5530v2 [nucl-ex]
[3] arXiv:1807.11321v2 [nucl-ex]
[4] arXiv:1505.08066v2 [hep-ph]
[5] Hagedorn, R., 1965, Nuovo Cim. Suppl. 3
[6] arXiv:1505.08066v2 [hep-ph]
[7] arXiv:1905.05736v3 [hep-ph]