Non-Extensive Approach to High-Energy Collisions

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Introduction

Strong correlations between particles can rule out the Boltzmann – Gibbs and rather lead to non-extensive statistics. This case is typical for heavy ion physics which can be a possible testbed for non-extensive thermodynamical phenomena, due to the fact that high-energy nuclear reactions involve strongly correlated processes. Non-extensive thermodynamics is a novel approach to investigate high-energy heavy ion collisions, furthermore it is particularly successful for describing the intermediate and high transverse momentum regimes. Based on this idea, we found that the hadron production in AuAu collisions at RHIC energies can be well fitted by the Tsallis–Pareto distribution.

Recent experimental data measured at the LHC in proton-proton collisions have also shown Tsallis–Pareto-like distributions, but the fitted parameters are not yet interpreted.

In this poster we present the re-parameterized fragmentation functions for charge-averaged pion yields by a Tsallis –Pareto-like distribution. We apply a suggested ansatz based on earlier work in order to satisfy the Dokshitzer–Gribov–Lipatov–Altarelli–Parisi (DGLAP) scale evolution equation. The inclusion of this new fragmentation model leads to a slightly modified curve in the pQCD improved parton model result, sup porting the applicability of our model.

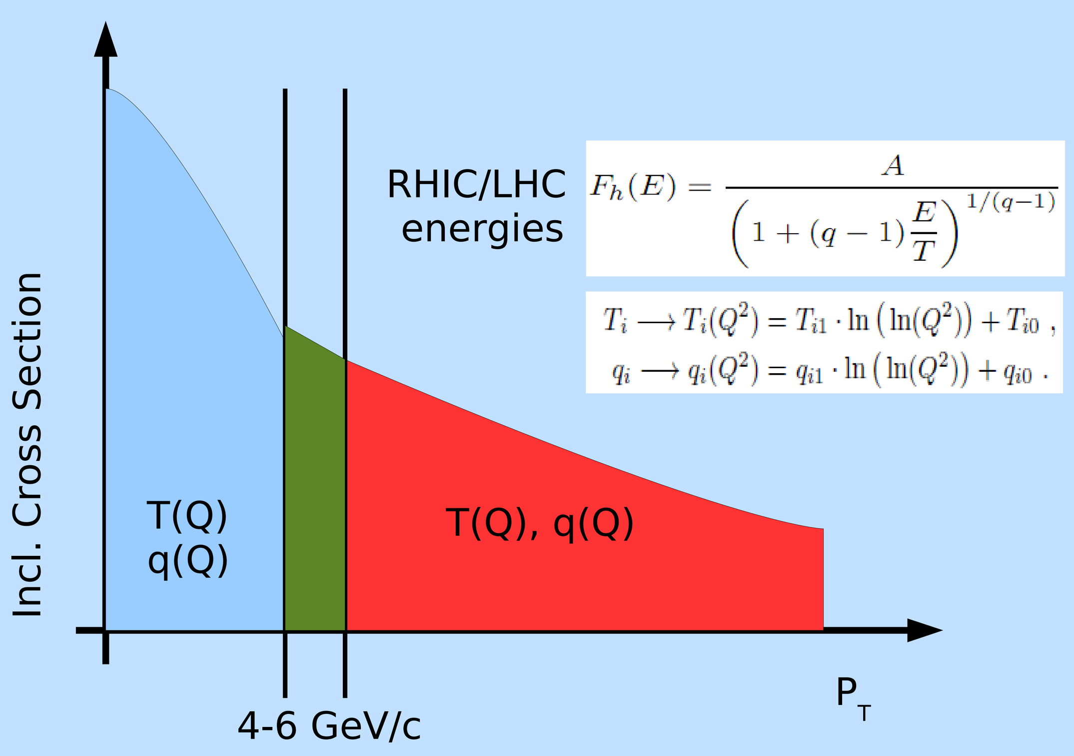

Figure 1: Inclusive spectra *at RHIC and LHC energies can be represent by a generalized Tsallis-Pareto distribution.*

Tsallis –Pareto Distribution for Proton-Proton Collisions

Based on an earlier test the Tsallis–Pareto-like distribution were found to be a good fit to various experimentally measured p_T spectra in electron-positron and proton-proton collisions in a wide energy range. Parallel to this, we found that an inclusion of a term ~$\ln(\ln Q^2)$ leads to parameters scaling with energy correctly. Relating these findings to a pQCD based parton model picture, the origin of the Tsallis–Pareto-distribution may arise from the final state, where strongly correlated multiparton states are hadronizing.

Our assumption: the hadronization (or fragmentation) should be the best candidate for the non-extensive processes yielding Tsallis–Pareto-distributions.

To test our assumption within the pQCD based parton model frame work, we parameterized a fragmentation function for charge-averaged pions using Tsallis–Pareto-like distribution. We used the form of the Tsallis–Pareto distribution for the hadronization including the Q^2 scaling:

$$D^{\pi}_{p_i}(z) \sim \left(1+(q_i-1)\cdot\frac{z}{T_i}\right)^{-1/(q_i-1)}$$

$$T_i \longrightarrow T_i(Q^2) = T_{i1}\cdot\ln\left(\ln(Q^2)\right) + T_{i0}$$
$$q_i \longrightarrow q_i(Q^2) = q_{i1}\cdot\ln\left(\ln(Q^2)\right) + q_{i0}$$

The temperatures $T_i(Q^2)$ and Tsallis-q parameters $q_i(Q^2)$ were fitted, and collected in Table 1. The Q^2-scaling of the parameters and *T-q* parameter space is plotted on Fig 2.

Table 1. Parameters for the Tsallis – Pareto distribution in all partonic channels for charg-averaged pions.

parton, i	T_{i1}	T_{i0}	q_{i1}	q_{i0}
$u, \bar{u}, d, \bar{d}$	-0.057753	0.239825	0.124000	0.860351
$s, \bar{s}$	-0.093988	0.343175	0.265042	0.384453
$c, \bar{c}$	-0.048170	0.205408	0.134546	0.762087
$b, \bar{b}$	-0.033599	0.156249	0.103565	0.803255
g	-0.118556	0.394749	0.318477	0.253205

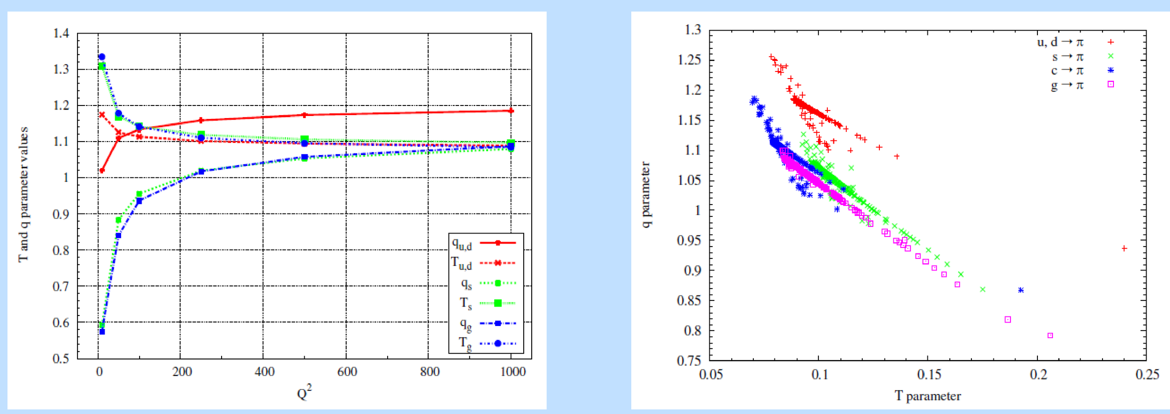

Figure 2: *The Q2-scaling, and parameter space of the Tsallis-Pareto distribution.*

Hadron Spectra using the fitted Tsallis–Pareto Distribution

The obtained parameters for were found to be in the following regions: for channels u and d in *0.7 <* $q_{u,d}$ *< 1.25* and in *0* GeV < $T_{u,d}$ < *0.3* GeV, meanwhile for the channels *s, c, b* and *g* were in *0 <* $q_{s,c,b,g}$ *< 1.25* and for the Tsallis temperature *0* GeV < $T_{s,c,b,g}$ < *0.2 − 0.4* GeV. On the other hand the population in the parameter space features two main branches: one for constituents and one sea and gluon contributions.

We found, that it satisfies the DGLAP scale evolution by construction, and is a good candidate for an easy parameterization. As a simple test of our re-parameterized fragmentation functions, we implemented them into a next-to-leading order (NLO) pQCD improved parton model framework. On Figure 3 we plotted the inclusive spectrum of a minimum bias pion production in 7 TeV center of mass energy proton-proton collision.

Calculations were carried out in a next-to-leading order pQCD based parton model framework, with MRST-(cg) parton distribution. For comparison we plotted two curves: one with AKK fragmentation function indicated by the dashed blue curve and the re-parameterized Tsallis–Pareto-like hadronization plotted with the solid red curve.

As Figure 3 presents, our result overlaps with the original AKK-based calculations, especially at the low momentum fraction values. On the other hand at high p_T the new distribution gives a slightly higher yield. The validity of our model might be clarified by future data from Large Hadron Collider's experiments.

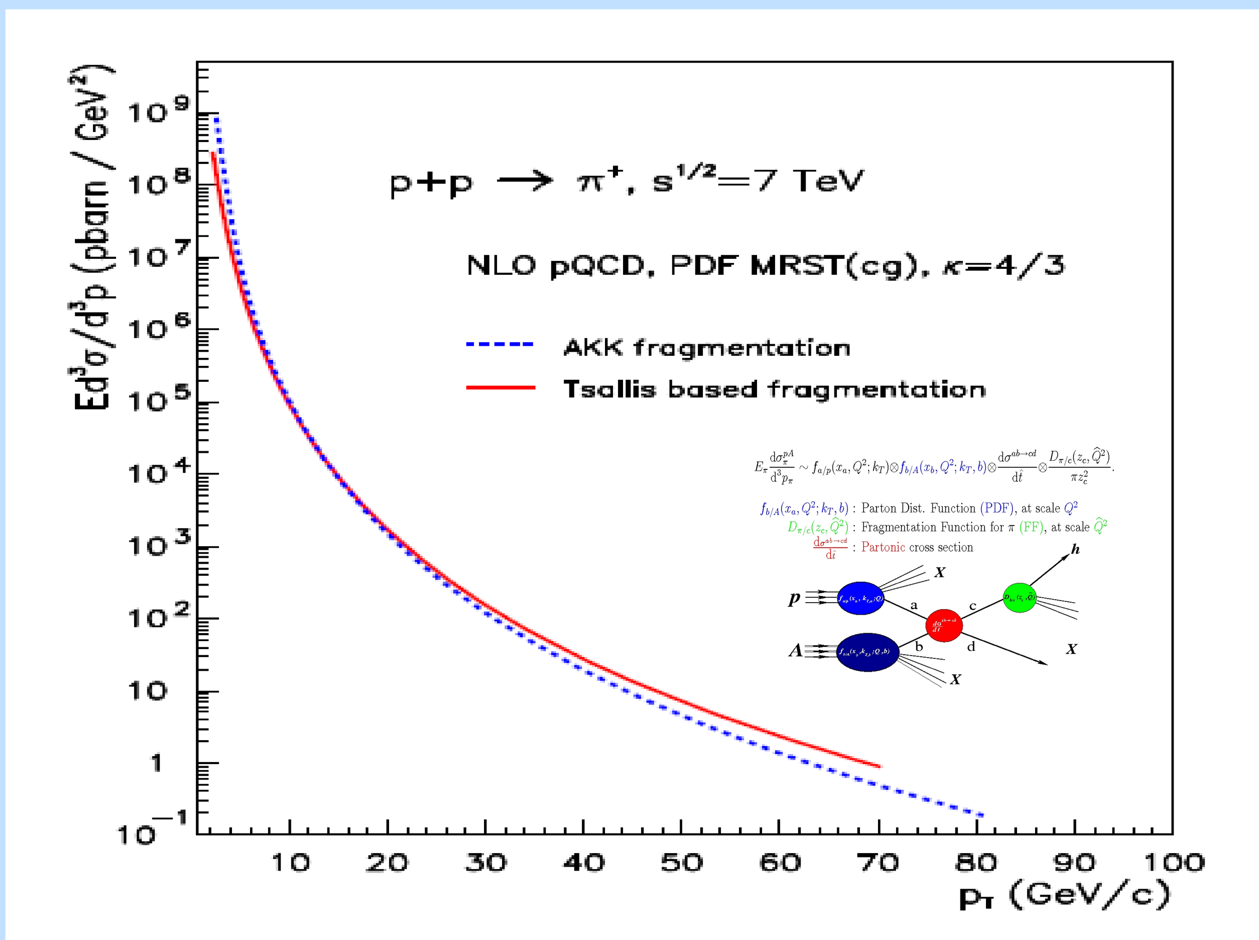

Figure 3: *The pQCD based parton model and an application reproducing pion spectra using Tsallis-Pareto-based fragmentation for 7 TeV LHC proton-proton collisions.*

ACKNOWLEDGEMENTS & REFERENCES

This work was supported by the Hungarian National Science Found OTKA No: PD73596, K68108 and the Eötvös University (GK & KU).

One of the authors (GGB) thanks to the János Bolyai Research Scholarship of the HAS.

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