Two component model with collective flow for hadroproduction in heavy-ion collisions.

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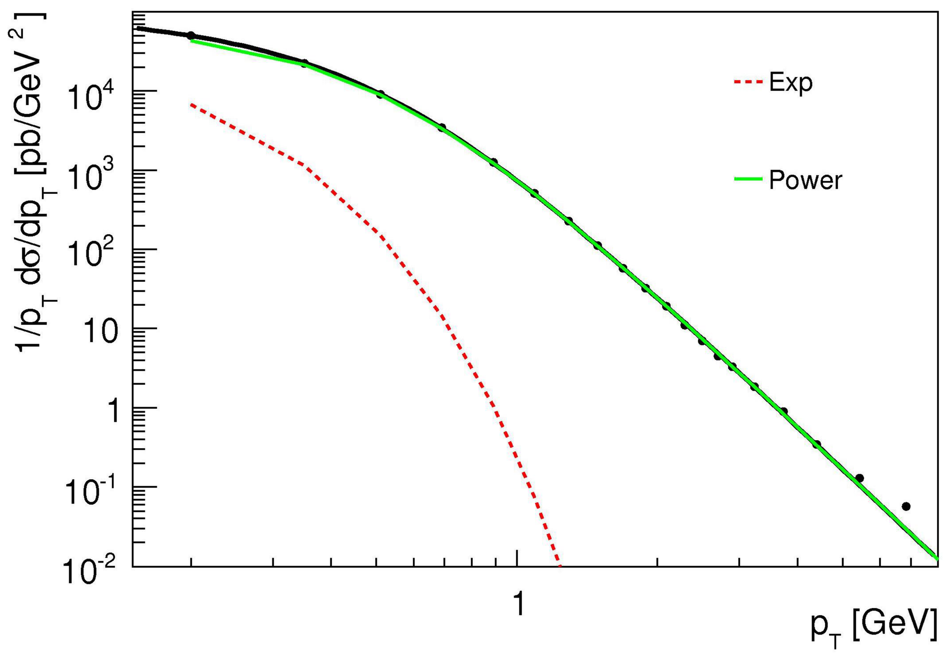
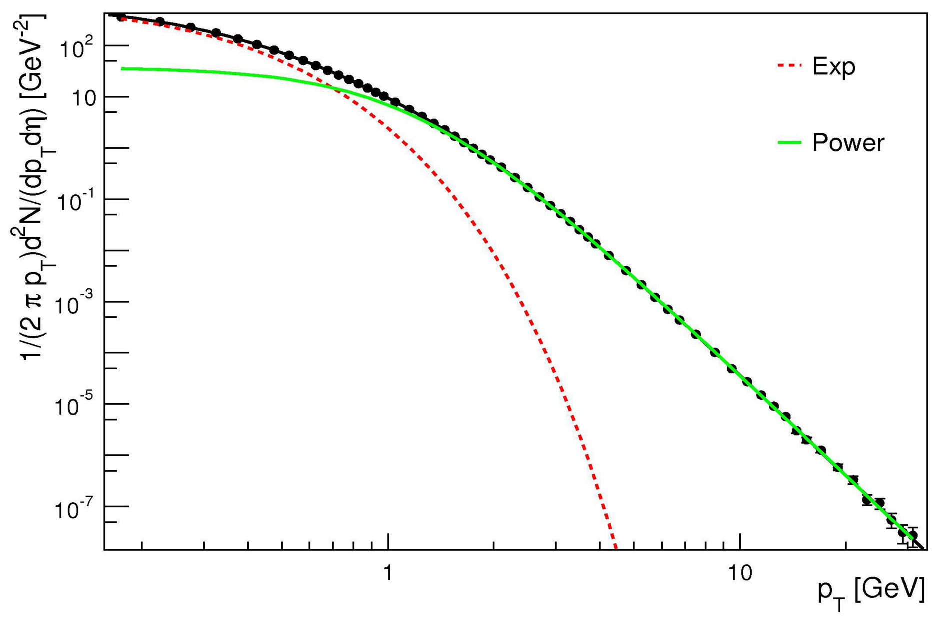
Introduction

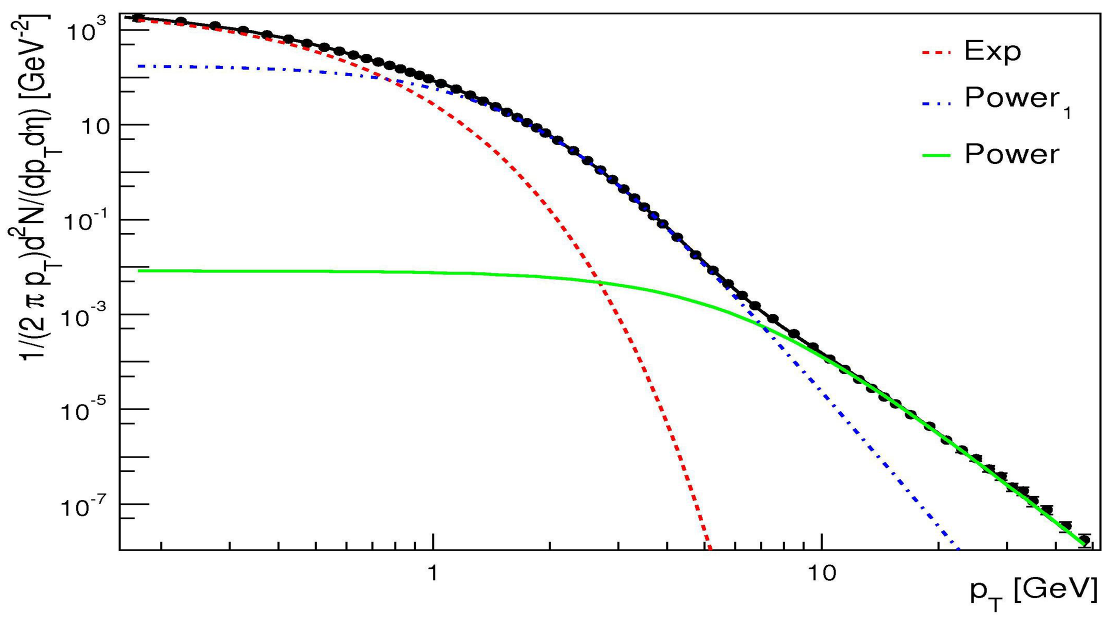
Recently, a unified approach to describe charged particles production in high-energy collisions and describing two distinct mechanisms of hadroproduction (exponential and power-law) has been proposed. According to this approach, the exponential part stands for the release of ”thermalized” particles by the preexisting valence quarks and a quark-gluon cloud coupled to them inside the colliding baryon. The power-law term accounts for the fragmentation of mini-jets formed by the secondary partons (gluons) produced with a relatively large k_T at the first stage of the collision, that can be described within the pQCD. From this qualitative picture of hadroproduction one can naively expect that the spectra of charged hadrons in γγ collisions should be described by the power-law term alone due to the absence of ”thermalized” quarks and gluons in the colliding systems. Thus, it is interesting to compare the shapes of charged particles produced in these two types of interactions (γγ and pp) with a more complex case of heavy-ion collisions.

Hierarchy in hadroproduction dynamics

$A/(1 + P_T^2/(T^2N))^N$ + $A_e \cdot \exp[-E_T/T_e]$ + $A_1/(1+ P_T^2/(T_1^2N_1))^{N1}$







γγ collision: a point like interaction that can be described in terms of pQCD and thus, needs a power-law term only in its spectrum.

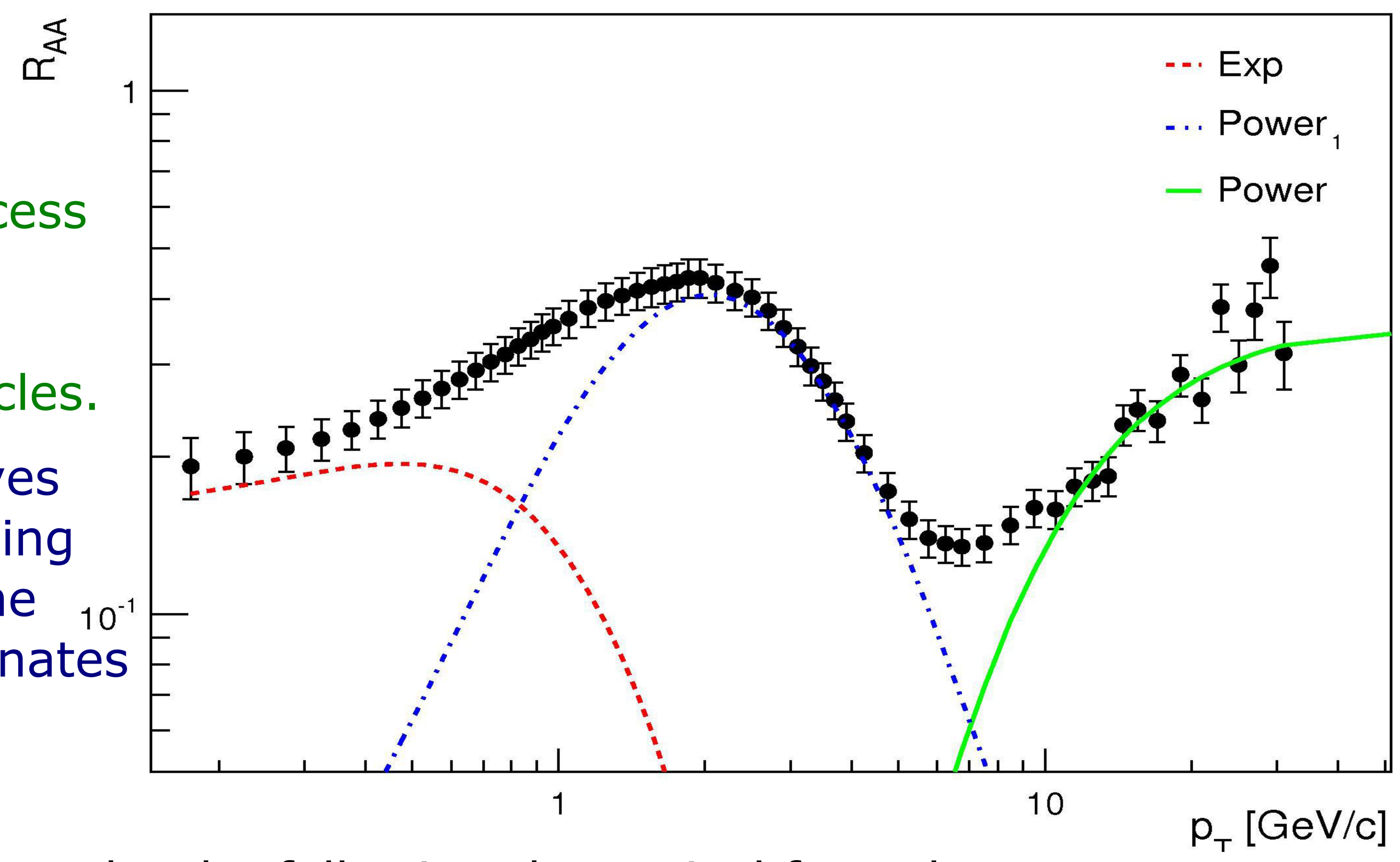
baryon-baryon collision: in addition to the mini-jet fragmentation of the virtual partons an exponential term standing for the release of thermalized particles due to preexisting quarks and gluons is added.

heavy-ion collision: due to the quenching of charged hadrons inside the nuclei the power-law term ’splits’ into two distributions with different parameters (the second closer to the exponent). Therefore, we need a sum of exponential and **2** power-law terms to describe the spectra.

Hadroproduction in heavy-ion collisions

The following picture for hadroproduction in heavy-ion collisions can be introduced:

1. The bulk of low-p_T particles originates from the ’quark-gluon soup’ formed in the heavy-ion collision and has an exponential p_T distribution.
2. The high-p_T tail accounts for the mini-jets that pass through the nuclei, the process that can be described in pQCD. When these jets hadronize into final state particles *outside the nuclei*, we get the same power-law term parameter N as in pp-collisions, resulting in a constant suppression (R_{AA}) of high-p_T (> 20 GeV) particles.
3. Mini-jet fragmentation into final state hadrons can also occur before the jet leaves the nuclei volume. The produced particles have to wade out through the nuclei, being affected by multiple rescatterings, thus their distribution becomes more close to the exponent, resulting in higher values of N_1 and T_1 of the power-law term, and dominates the mid-p_T region. This process can’t be described in pQCD, however.



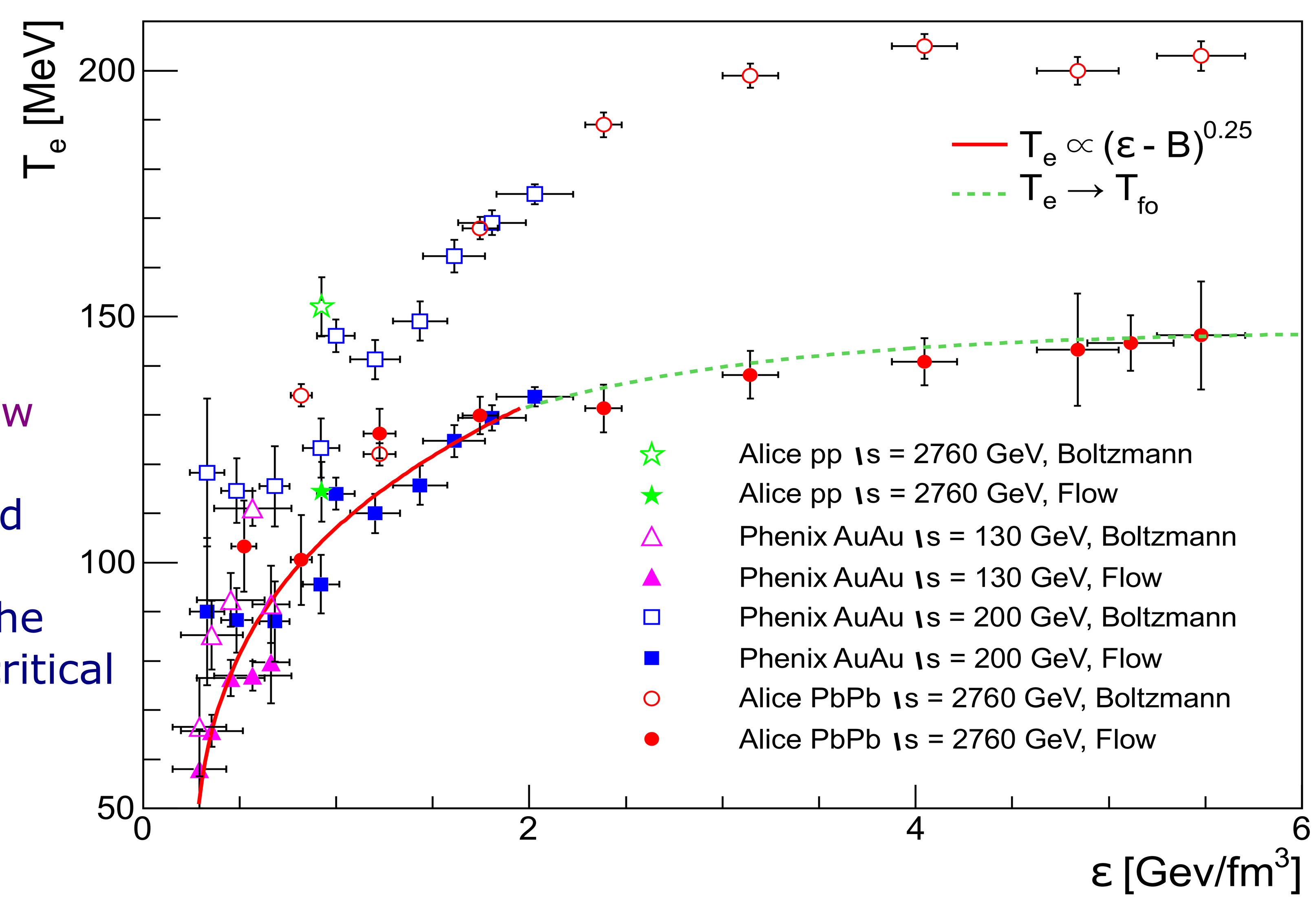
Extension with collective flow

To take the collective flow into account one can should replace the Boltzmann exponent by the following theoretical formula:

$$\frac{\mathrm{dn}}{p_T \mathrm{d}p_T} \propto \int_0^R r\, \mathrm{d}r\, m_T\, I_0\left(\frac{p_T \sinh\rho}{T_e}\right) K_1\left(\frac{m_T \cosh\rho}{T_e}\right)$$

The introduced approach allows to extract the 'thermalized' production of charged hadrons from the whole statistical ensemble:

1. A smooth transition in the T_e values as a function of energy density between RHIC and LHC data is observed.
2. $\varepsilon \sim T_e^4 + B$, which is consistent with the bag Model or Stefan-Boltzmann law for the black body radiation.
3. For high energy densities T_e reaches a certain limit. This might be explained from the QGP theory that considers the phase transition temperature T_c from QGP to final state hadrons. Indeed, for high values of ε one can notice, that the observed freeze-out temperature is $T_{fo} \approx 145$ MeV, and is slightly below the critical temperature $T_c \sim 155{-}160$ MeV for QGP obtained in different calculations.
4. The temperature obtained from the fit without 'collective flow' turns out to be much higher than one can expect ~200 MeV.



Conclusions

1. The spectra of charged hadron production in heavy-ion collisions have been compared with pp and γγ interactions using the recently introduced two component model.
2. Hierarchy in hadroproduction dynamics was observed and picture for hadroproduction in heavy-ion collisions has been introduced.
3. The hydrodynamic extension of this parameterization accounting for the collective motion in heavy-ion collisions was suggested.
4. The temperature of the final state hadrons coming from the ’thermalized’ part of the spectra have been studied as a function of energy density using both RHIC and LHC data and the behavior that might be explained in terms of QGP formation has been observed.

arxiv: 1405.3055