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# Charged hadron distributions in a two component model

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**Abstract**

Inclusive charged hadron cross sections, $d\sigma/d\eta$, and $d^2\sigma/(d\eta dp_T^2)$ are considered within the two component model, which combines the power-like and the exponential terms in $p_T$. The observed dependences of the spectra shape on energy and pseudorapidity qualitatively agree with the proposed model for hadroproduction. A short overview of the results published recently is presented.

*Keywords:* Charged hadron spectra, transverse momentum, phenomenology

At high energies, $\sqrt{s}$, the hadron-hadron interaction and the multiparticle production are usually considered in terms of the pomeron exchange. Besides the single pomeron exchange there are more complicated contributions described by the multi-pomeron diagrams in the framework of the Reggeon Field Theory (RFT)[1]. This multi-pomeron terms account for the absorptive corrections and rescattering effects.

In perturbative QCD (pQCD) the pomeron exchange amplitude is given by the set of the "ladder-like" diagrams build up of the (reggeized) gluons. These diagrams sum up all the contributions where the small value of the QCD coupling constant $\alpha_s$ is compensated by the large value of $\ln s$ [2]. In the Leading Log approximation the intercept of this BFKL pomeron $\alpha_P(0) = 1 + \Delta$ turns out to be rather large [3]:

$$\Delta = \frac{\alpha_s N_c}{\pi} \cdot 4 \ln 2 \, . \qquad (1)$$

Numerically it leads to $\Delta > 0.5$. Accounting for the 'next-to-leading-Log' (NLL) corrections we get a lower, but still rather large intercept. The resummation of the NLL contributions gives $\Delta \sim 0.2 - 0.3$ [4].

On the other hand, the high energy cross-sections grow much slowly, like $\sigma_{tot} \propto s^{\Delta_{eff}}$ with $\Delta_{eff} \sim 0.1$ [5]. This fact is explained by large absorptive corrections caused by the multi-pomeron diagrams. Due to so large absorptive (multi-pomeron) effects it is not easy to study the properties of the *individual* pomeron experimentally.

Therefore, it is interesting to see the energy dependence of the inclusive cross sections (and the mean transverse momenta, $< p_T >$, of secondaries) obtained from the fit where their spectra are described using the *two component* ansatz [6] including two qualitatively different contributions: with a power and an exponential $p_T$ behavior:

$$\frac{d\sigma}{p_T dp_T} = A_e \exp\left(-E_{Tkin}/T_e\right) + \frac{A}{(1 + \frac{p_T^2}{T^2 \cdot n})^n}, \qquad (2)$$

where $E_{Tkin} = \sqrt{p_T^2 + M^2} - M$ with M equal to the produced hadron mass. $A_e, A, T_e, T, n$ are the free parameters to be determined by fit to the data. The typical charged particle spectrum fitted with this formula is shown in figure 1).

The power-like component is mainly originated from a relatively large $p_T$ domain, that is from the mini-jet fragmentation, while the exponential part accounts for some "thermalization" caused by the final state rescattering in the parton cloud and the "hadron gas" formed

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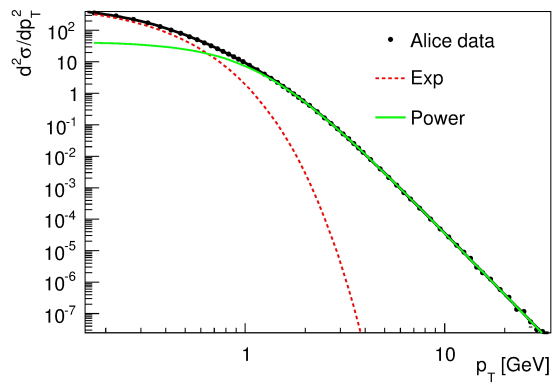


Figure 1: Charged particle spectrum [11] fitted to the function (2): the red (dashed) curve shows the exponential term and the green (solid) one stands for the power-like term.

by the secondaries. Schematically figure 2 shows these two sources of particles produced in high energy baryonic collisions.

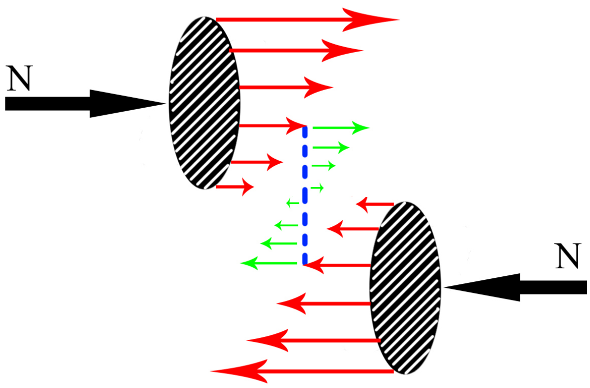


Figure 2: Two different sources of hadroproduction: red arrows - particles produced by the existing partons, green - particles produced via the mini-jet fragmentation.

Recall that according to the AGK cutting rules [7] the corrections caused by the multi-pomeron graphs are almost absent in the single particle inclusive cross sections $d\sigma(a+b\to c+X)/d^3p$. Indeed, in this case there are no contribution from the diagrams where an additional pomeron crosses the rapidity of detected particle $c$. This means that here we have no corrections from the non-enhanced, eikonal-like diagrams. Within the eikonal (or multi-channel eikonal) models such inclusive cross section is described just by the *one* pomeron exchange. Moreover, thanks to the AGK rules, an important part of the 'enhanced' absorptive corrections (which account for the rescattering and the interactions between the intermediate particles in the pomeron ladder and are "enhanced" by the multiplicity of these intermediate particles) is canceled as well. The remaining enhanced diagrams, corresponding to the interactions between the intermediate particles in only one hemisphere (between the hadrons $a$ and $c$ or $b$ and $c$) are suppressed for the power-like part of the spectra due to a relatively large $q_t$ of the original mini-jet which acts as a source of this power-like component.

Thus, the behavior of the power-like part of single particle inclusive cross sections provides a most direct information about the 'bare' pomeron properties. In particular, we expect that the particle density $d\sigma^{power}/d\eta$ should increase with energy as

$$\frac{d\sigma^{power}}{d\eta} \propto s^{\Delta_P}\,, \tag{3}$$

where $\alpha_P(0) = 1 + \Delta_P$ is the true intercept of the initial (bare) pomeron.

This effect has been studied recently [8] by fitting available experimental data on charged hadron production in $pp$-collisions from ISR to LHC energies [9, 10, 11, 12] by the parameterisation introduced (2) and integrating power-like and exponential contributions separately over $p_T^2$. As it is seen in Fig. 3 for the power-like part of the spectra we observe $\Delta \simeq 0.25$ - close to the value expected for the pQCD (BFKL) pomeron after the resummation of the NLL corrections. The value of $\Delta$ coming from the 'exponential' component is lower ($\simeq 0.15$) since it is strongly affected by absorptive corrections.

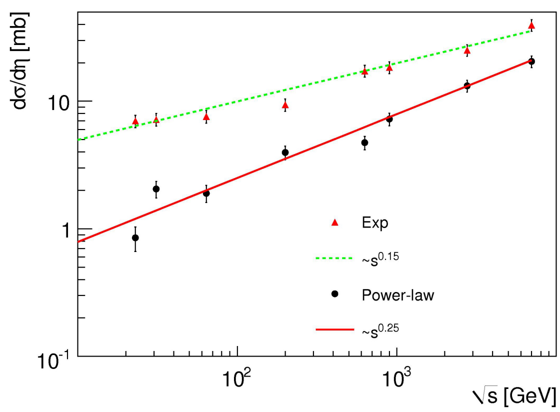


Figure 3: Particle densities $d\sigma/d\eta$ as function of c.m.s energy $\sqrt{s}$ in $pp$-collisions [9, 10, 11, 12] calculated for power-like and exponential contributions of (2) separately.

Let us now discuss the charged particle production in $pp$ collisions as a function of pseudorapidity in terms of the qualitative picture for hadroproduction introduced above. From the naive point of view, hadrons produced via the mini-jet fragmentation should be concentrated in the central rapidity region ($\eta \sim 0$), while those coming from the proton fragmentation are expected to dominate at high values of $\eta$ due to non-zero momenta of the initial partons along the beam-axis. This prediction has been checked recently [13] on the data published by the UA1 experiment [11] which are presented as cross-sections $d^2\sigma/(d\eta dp_T^2)$ for $pp$ collisions in five pseudorapidity bins, covering the total rapidity interval $|\eta| < 3.0$.

The contributions to the charged particle production from the exponential and power-like terms of eq. (2) can be studied separately as function of $\eta$. Figure 3 shows these contributions calculated from the fit (2) to the experimental data [11] (green triangles and red circles).

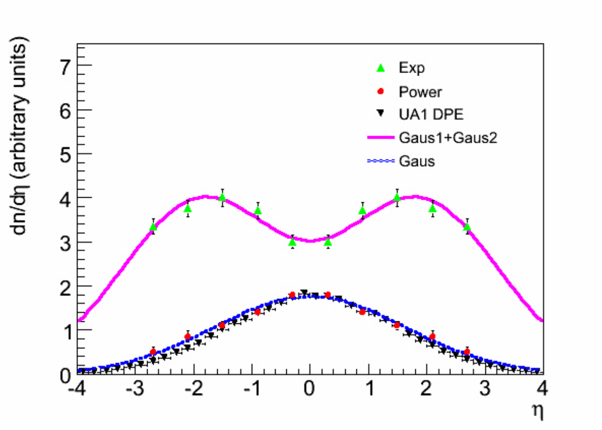


Figure 4: Particle distributions calculated for exponential and power-like contributions separately (green triangles and red circles) and fitted with Gaussian distributions (**??**) (blue dashed line) and (**??**) (solid magenta line), respectively. Experimental data on double-pomeron exchange (DPE) [14] (black inversed triangles) is presented with arbitrary normalization.

In addition, available data on the double-pomeron exchange measured at the same c.m.s. energy by the UA1 Collaboration [14] is shown in figure 3 with black inversed triangles. One can observe a rather good agreement between these data [14] and the shape of the power-law term contribution (shown with red circles in figure 3) calculated from the fit (2), supporting the qualitative picture for hadroproduction described above. Cuts on the rapidity gaps used to select the DPE events squeeze the measured distribution, excluding events with a large $\eta$, close to the edges of the available phase space. On the other hand, particles near these edges originate mainly from the exponential contribution. Therefore, we do not expect too much difference in the distributions for central $\eta$ corresponding to the power-like term in comparison with the Minimum Bias (MB) events. Indeed, as seen in figure 3, the distribution of the power-like component calculated from our fit (red circles) is a bit wider than that measured by the UA1 collaboration in DPE events [14] (black inversed triangles).

In conclusion, inclusive charged hadron cross-sections, $d\sigma/d\eta$, and $d^2\sigma/(d\eta dp_T^2)$ have been considered within the two component model as a function of c.m.s. energy $\sqrt{s}$ and pseudorapidity $\eta$. The observed dependences have been discussed and shown to qualitatively agree with the qualitative model introduced and with that expected from the Regge theory with the perturbative QCD pomeron.

## References


[1] V.N. Gribov, A Reggeon diagram technique, Sov. Phys. JTEP, 26 (1968) 414;
P. Collins, An introduction to Regge Theory and High-Energy Physics. Cambridge, 1977

[2] V.S. Fadin, B.L. Ioffe and L.N. Lipatov, *Quantum Chromodynamics: Perturbative and nonperturbative aspects*. Camb. Univ. Press, 2010.

[3] V.S. Fadin, E.A. Kuraev, and L.N. Lipatov, Phys. Lett. **B60**, 50 (1975);
Sov. Phys. JETP **44**, 443 (1976); **72**, 377 (1977) [**45**, 199 (1977)];
I.I. Balitsky and L.N. Lipatov, Sov. J. Nucl. Phys. **28**, 822 (1978).

[4] M. Ciafaloni, D. Colferai, and G. P. Salam, Phys.Rev. **D60**, 114036 (1999), hep-ph/9905566;
G. P. Salam, JHEP **9807**, 019 (1998), hep-ph/9806482;
V. A. Khoze, A. D. Martin, M. G. Ryskin, and W. J. Stirling, Phys.Rev. **D70**, 074013 (2004), hep-ph/0406135.

[5] A. Donnachie and P.V. Landshoff, Phys. lett. B296 (1992) 227.

[6] A. A. Bylinkin and A. A. Rostovtsev, Phys. Atom. Nucl. **75** (2012) 999 Yad. Fiz. **75** (2012) 1060;
A. A. Bylinkin and A. A. Rostovtsev, arXiv:1008.0332 [hep-ph].

[7] V.A. Abramovsky, V.N. Gribov and O.V. Kancheli, Sov. J. Nucl. Phys. **18**, 308 (1973).

[8] A. A. Bylinkin and M. G. Ryskin Phys. Rev. D **90** (2014) 017501 [arXiv:1404.4739 [hep-ph]].

[9] B. Alper *et al.* [British-Scandinavian Collaboration], Nucl.Phys.B **100**:237,1975.

[10] A. Adare *et al.* [PHENIX Collaboration], Phys. Rev. C **83** (2011) 064903 [arXiv:1102.0753 [nucl-ex]].

[11] G. Bocquet *et al.* [UA1 Collaboration], Phys.Lett.B**366**:434-440,1996

[12] B. B. Abelev *et al.* [ALICE Collaboration], Eur. Phys. J. C **73** (2013) 2662 [arXiv:1307.1093 [nucl-ex]].

[13] A. A. Bylinkin and A. A. Rostovtsev, Nucl. Phys. B **888** (2014) 65 [arXiv:1404.7302 [hep-ph]].

[14] D. Joyce, A. Kernan, M. Lindgren, D. Smith, S. J. Wimpenny, M. G. Albrow, B. H. Denby and G. Grayer, Phys. Rev. D **48** (1993) 1943.