Transverse momentum distributions and $p_t - N_{ch}$ correlations in Extended Multipomeron Exchange Model

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Introduction

The multipomeron exchange model was considered earlier in papers [1] - [5]. Within the framework of this model, it was possible to successfully describe the charged multiplicity (N_{ch}), mean transverse momentum (p_t) and p_t-N_{ch} correlations in pp and $p\bar{p}$ collisions over a wide energy range (from ISR to LHC). It allowed also to reproduce the growth of the yields of strange, multi-strange and charm particles as a function of multiplicity for pp, $p-Pb$ and $Pb-Pb$ collisions at the LHC energy. For this, in particular, the general idea of the Schwinger mechanism of particle production from a string [6] was used, where the transverse momentum distribution of charged particles from a string has a Gaussian form, and in case of string overlap the effective string tension was related to the number of strings. However, experimental data show that the pt-spectra of particles produced in pp collisions are better described by the thermal model. To solve this problem, we introduced the thermal-like pt distribution function which can be considered as averaging out over string tension fluctuations [7]. We calculated p_t-spectra and p_t-N_{ch} correlations functions for $pp-$collisions at the LHC energy in extended multipomeron exchange model and compared the results with the experimental data [8].

Transverse momentum distribution

1. Multipomeron Exchange Model:

$\rho(N_{ch}, p_t)$ is the distribution of N_{ch} particles over p_t :

$$\rho(N_{ch}, p_t) = \frac{C_w}{z}\sum_{n=1}^{\infty}\left(1-\exp(-z)\sum_{l=0}^{n-1}\frac{z^l}{l!}\right)\cdot\exp(-2n\kappa\delta)\frac{(2n\kappa\delta)^{N_{ch}}}{N_{ch}!}\cdot\frac{1}{n^\beta t}\exp\left(-\frac{\pi p_t^2}{n^\beta t}\right). \quad (1)$$

Here, C_w is a normalization factor:

$$C_w = \left[\sum_{n=1}^{\infty}\frac{1}{nz}\left(1-exp(-z)\sum_{l=0}^{n-1}\frac{z^l}{l!}\right)\right]^{-1} = \left[\sum_{n=1}^{\infty}\frac{1}{nz}\left(1-\frac{\Gamma(n,z)}{\Gamma(n)}\right)\right]^{-1}.$$

$$z = \frac{2C\gamma s^\Delta}{R^2+\alpha'\ln(s)},\ \ \Delta = 0.139,\ \ \alpha' = 0.21\,GeV^{-2},\ \ \gamma = 1.77\,GeV^{-2},\ \ R_0^2 = 3.18\,GeV^{-2},\ \ C = 1.5\,.$$

$$t = 0,566\,GeV^2\,,\ \ k = 0.255 + 0.0653\,\ln\sqrt{s}\,,\ \ \beta = 1.16\left[1-\left(\ln\sqrt{s}-2.52\right)^{-0.19}\right].$$

Transverse momentum distribution is defined as follows:

$$\frac{d^2N_{ch}}{d\eta dp_t} \equiv P(p_t) = \sum_{n=1}^{\infty} N_{ch}\cdot\rho(N_{ch}, p_t)\,. \quad (2)$$

2. Transverse momentum distribution with simplify Schwinger mechanism:

$$P_1(p_t) = \frac{2\kappa\delta C_w}{z}\sum_{n=1}^{\infty}\left(1-\frac{\Gamma(n,z)}{\Gamma(n)}\right)\cdot\left(\frac{1}{n^\beta t}\right)\cdot\exp\left(-\frac{\pi p_t^2}{n^\beta t}\right). \quad (3)$$

3. Transverse momentum distribution with Bialas transform (1):

$$P_2(p_t) = \frac{2\kappa\delta C_w}{\pi z}\sum_{n=1}^{\infty}\left(1-\frac{\Gamma(n,z)}{\Gamma(n)}\right)\cdot\frac{1}{\sqrt{n^\beta t}}\cdot\left(\frac{1}{p_t}\right)\cdot\exp\left(-2p_t\sqrt{\frac{1}{n^\beta t}}\right). \quad (4)$$

Results

$\sqrt{s}$	900 GeV	2,76 TeV	7 TeV
$t_{\text{Schwinger}}$	0.5 GeV^2	0.529 GeV^2	0.542 GeV^2
t_{Bialas}	0.515 GeV^2	0.568 GeV^2	0.588 GeV^2
$\beta_{\text{Schwinger}}$	0.3	0.32	0.35
β_{Bialas}	0.2	0.2	0.30
$k_{\text{Schwinger}}$	0.568	0.801	0.996
k_{Bialas}	0.76	1.0	1.309
$\chi^2/NDF_{Schwinger}$	3298/29	2772/29	2673/29
χ^2/NDF_{Bialas}	192/29	130/29	94/29

Transverse momentum distributions

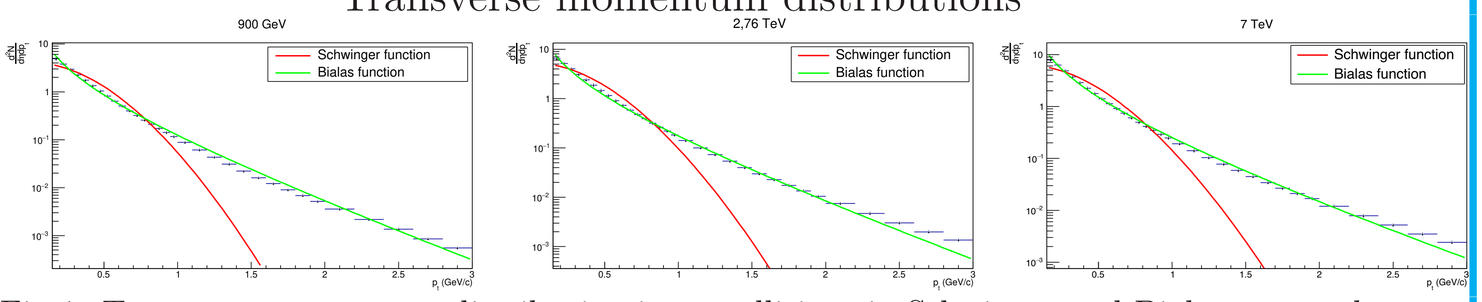

Fig 1. Transverse momentum distribution in pp collisions in Schwinger and Bialas approaches compared with experimental data [8].

Conclusions

We have shown that the thermal-like function for transverse momentum obtained on the basis of Bialas work (4) describes the p_t spectra in pp collisions much better than the Schwinger approach (3), this is especially clear at high values of p_t. We obtained that $p_t - N_{ch}$ correlations can be described in the same way as for Schwinger distribution.
In future work, we plan to perform simultaneous fitting of the p_t spectra and $p_t - N_{ch}$ for the parameter estimation and also to consider optimizing the N_{ch} distribution.

References

[1] Armesto N., Derkach D.A., Feofilov G.A. Phys. Atom. Nucl. 2008, **71**, 2087–2095.
[2] Bodnia E., Derkach D., Feofilov G., Kovalenko V., Puchkov A. PoS QFTHEP2013 2013, 60.
[3] Kovalenko V.N., Puchkov A.M., Feofilov G.A. Bull. Russ. Acad. Sci. Phys. 2016, **80**, 966–969.
[4] Feofilov G., Kovalenko V., Puchkov A. EPJ Web Conf. 2018, **171**, 18003.
[5] Kovalenko V., Feofilov G., Puchkov A., Valiev F. Universe 2022, **8**, 246.
[6] Schwinger J. S. Phys. Rev. 1951, **82**, 664–679.
[7] Bialas A. Phys. Lett. B 1999, **466**, 301–304.
[8] ALICE Collaboration, Eur. Phys. J. C 2013, **73**, 2662.

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