Unintegrated parton distributions and pion production in pp collisions at SPS and RHIC energies

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Inclusive cross sections for pion production in pp collisions are calculated for the first time fully based on unintegrated gluon, quark and antiquark distributions (uPDF). We use recently developed Kwieciński uPDF's and different phenomenological fragmentation functions (FF) from the literature. In addition to the $gg \rightarrow g$ diagram we include also $gq \rightarrow q$ and $qg \rightarrow q$ diagrams for inclusive parton production. The cross section for pions is obtained then by convoluting the inclusive parton distributions and FFs. Applications for SPS and RHIC are shown.

1. INTRODUCTION

The distributions of mesons at large transverse momenta in pp or $p\bar{p}$ collisions are usually calculated in the framework of perturbative QCD using collinear factorization (see e.g. [1,2]) In order to extend the calculation towards lower values of meson transverse momenta it was suggested to add an extra Gaussian distribution in transverse momentum [3,4]. It becomes clear that this procedure is effective in the following sense. The transverse momentum originates either from the nonperturbative "really internal" momentum distributions of partons in nucleons (of the order of a fraction of GeV) and/or is generate dynamically as the inital state radiation process (of the order of GeV). In principle, the second component depends on the value of longitudinal momentum fraction.

Recently Kwieciński and collaborators [5] have shown how to solve the so-called CCFM equations by introducing uPDF's in the space conjugated to the transverse momenta. In the following we shall use those uPDF's for pion production at SPS, ISR and RHIC energies.

2. FORMALISM

The approach proposed by Kwieciński is very convenient to introduce the nonperturbative effects like internal (nonperturbative) transverse momentum distributions of partons in nucleons. It seems reasonable, at least in the first approximation, to include the non-

perturbative effects in the factorizable way

$$\tilde{f}_q(x, b, \mu^2) = \tilde{f}_q^{pert}(x, b, \mu^2) \cdot F_q^{np}(b) \ . \tag{1}$$

In the following, for simplicity, we use a flavour and x-independent form factor

$$F_g^{np}(b) = F_q^{np}(b) = F_{\bar{q}}^{np}(b) = F^{np}(b) = \exp\left(-\frac{b^2}{4b_0^2}\right) \ . \tag{2}$$

Within k_t-factorization approach there are three basic diagrams for inclusive parton production shown in Fig.1. The formulae for inclusive parton production, after some minor
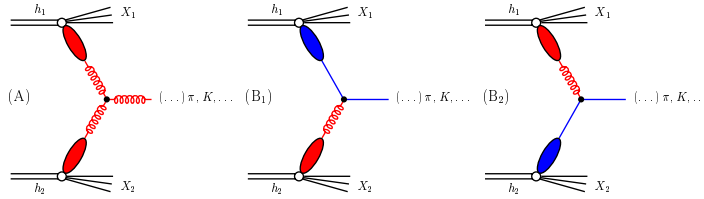

Figure 1. Leading-order diagrams for inclusive parton production

approximation [7], can be written in the equivalent and compact way in the so-called impact parameter space

for diagram A:

$$\frac{d\sigma^A}{dy d^2 p_t} = \frac{16 N_c}{N_c^2 - 1} \frac{1}{p_t^2} \alpha_s(p_t^2) \int \tilde{f}_{g/1}(x_1, b, \mu^2) \, \tilde{f}_{g/2}(x_2, b, \mu^2) J_0(p_t b) \, 2\pi b db \ , \tag{3}$$

for diagram B_1:

$$\frac{d\sigma^{B_1}}{dy d^2 p_t} = \frac{16 N_c}{N_c^2 - 1} \left(\frac{4}{9}\right) \frac{1}{p_t^2} \alpha_s(p_t^2) \sum_f \int \tilde{f}_{q_f/1}(x_1, b, \mu^2) \, \tilde{f}_{g/2}(x_2, b, \mu^2) J_0(p_t b) \, 2\pi b db \ , \tag{4}$$

for diagram B_2:

$$\frac{d\sigma^{B_2}}{dy d^2 p_t} = \frac{16 N_c}{N_c^2 - 1} \left(\frac{4}{9}\right) \frac{1}{p_t^2} \alpha_s(p_t^2) \sum_f \int \tilde{f}_{g/1}(x_1, b, \mu^2) \, \tilde{f}_{q_f/2}(x_2, b, \mu^2) J_0(p_t b) \, 2\pi b db \ . \tag{5}$$

The Kretzer FFs (see e.g.[6]) are used to convert partons to hadrons. Details of the hadronization procedure are explained in [7].

3. RESULTS

3.1. SPS energies

In Fig.2 we compare our model invariant cross sections for $pp \to \pi^+$ (left panel) and $pp \to \pi^-$ (right panel) as a function of pion transverse momentum at W = 27.4 GeV for different values of the parameter b_0 in Eq.(2). In principle, our result should not exceed experimental data especially in the perturbative regime of $p_t > 2$ GeV where the perturbative $2 \to 2$ parton subprocesses are crucial. This limits the value of the nonperturbative form factor to $b_0 > 0.5$ GeV^{-1}.
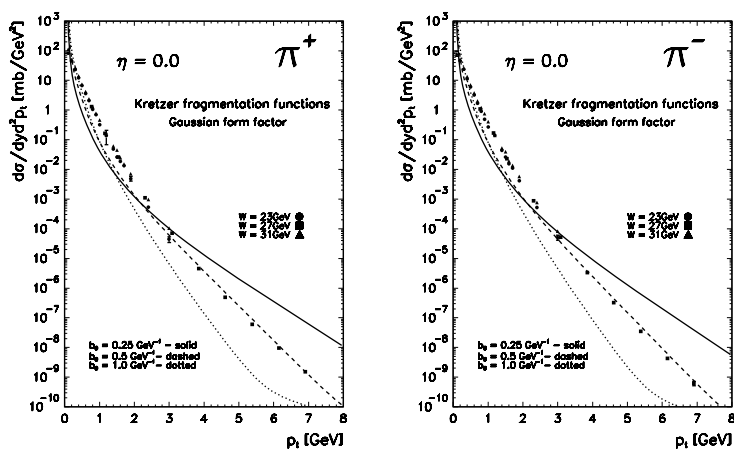
Figure 2. Invariant cross section as a function of transverse momentum of π^+ (left panel) and π^- (right panel) for $\eta = 0$, W = 27.4 GeV and different values of b_0. Experimental data for W = 23, 31 GeV from [8] and for W = 27.4 GeV [9] are shown for comparison.

3.2. RHIC energies

In Fig.3 we present result of our calculations at the RHIC energy W = 200 GeV again for different b_0 and Kretzer FFs [6]. While at large (pseudo)rapidities ($\eta = 2.2, 3.2$) our results (negative pions) are quite compatible with the BRAHMS data for negative hadrons, there seems to be a missing strength at more central (pseudo)rapidities ($\eta = 0.0, 1.0$), i.e. in the case when the sum of positively and negatively charged hadrons is measured. It is not clear to us if the missing strength is due to p or K^+. Much more results and comparison with recent RHIC data will be shown soon in [10].

4. CONCLUSIONS

We have extended the approach of unintegrated gluon distribution to particle production by including also unintegrated quark/antiquark unintegrated distributions. We find that the new contributions are comparable to the purely gluonic one at midrapidities and dominate in the fragmentation region. The new mechanisms are responsible for $\pi^+ - \pi^-$ asymmetry, especially at SPS energies [7,10].

Inclusive distributions in transverse momentum of pions for both SPS and RHIC energies have been shown here for illustration. A rather good agreement with experimental data is obtained without introducing so-called K-factors and/or initial (internal) transverse momenta by hand. In our approach transverse momentum is generated to large extend perturbatively by solving coupled equations for UPDF's. Therefore, in contrast to the standard collinear approach, in our approach the range of applicability can be extended towards much lower transverse momenta.
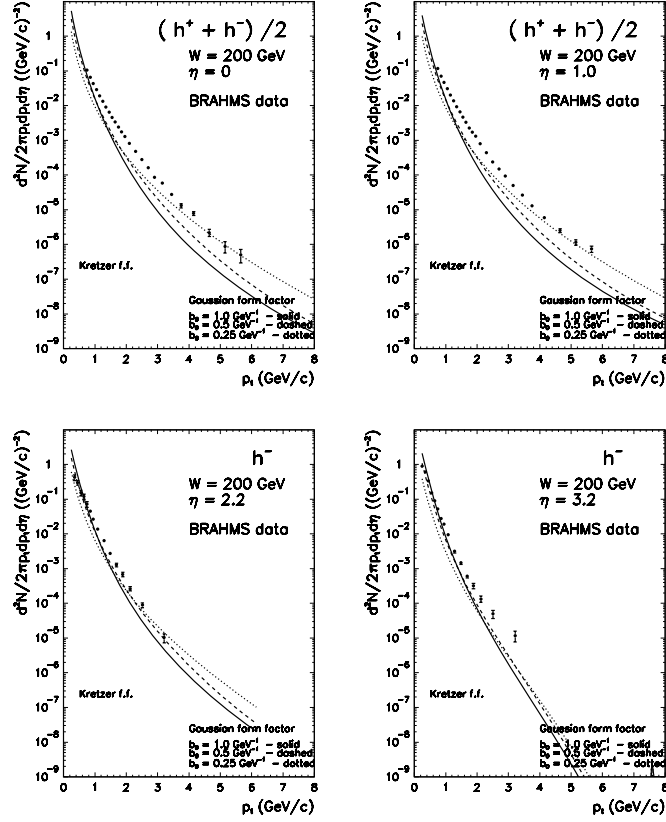
Figure 3. Invariant cross section for charged particle production for different pseudora-pidities at W = 200 GeV. The lines represent results obtained within our k_t-factorization approach. The BRAHMS collaboration experimental data [11] are shown for comparison.

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