Feynman Scaling Violation due to Baryon Number Transfer in Rapidity Space

G.H. Arakelyan[1], C. Merino[2], C. Pajares[2], Yu.M. Shabelski[3]

1 Yerevan Physics Institute
Yerevan, Armenia
2 Departamento de Física de Partículas
Instituto Galego de Altas Enerxías (IGAE)
Universidade de Santiago de Compostela
Galiza, Spain
3 Petersburg Nuclear Physics Institute
Gatchina, St.Petersburg, Russia

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Main Aim:

The LHCf Collaboration is studying the Feynman scaling violation looking at γ and neutron spectra.

The preliminary simulations made by LHCf collaboration shows that one model (QCSJET2) predicts the violation of Feynman scaling and the another model (Sybill) predict its conservation.

Alessa Tricomi. LHCf Collaboration, The 2007 Conference on High Energy Physics, Journal of Physics: Conference series 110 (2008) 072044

We consider the effects of Feynman scaling violation connected to large distance baryon diffusion in rapidity space for p and n production in high energy pp collisions.

Experimentally the differences in the yields of baryons and antibaryons produced in the central (midrapidity) region of high energy pp interactions are significant.

Evidently, the appearance of the positive baryon charge in the central region of pp collisions should be compensated by the decrease of the baryon multiplicities in the fragmentation region, leading to additional Feynman scaling violation.

The inclusive spectra of a secondary hadron h are determined in QGSM by the convolution of the quark and diquark distribution functions with the corresponding fragmentation functions.

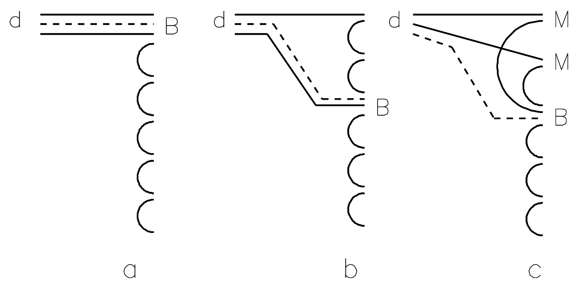
The diquark and quark distributions, as well as the fragmentation functions, are determined by Regge phenomenology.

The corresponding formulae were presented in

A.B. Kaidalov, Sov. J. Nucl. Phys. 45, 902 (1987); Yad. Fiz. 43, 1282 (1986)

G.H. Arakelyan, A. Capella, A.B. Kaidalov, and Yu.M. Shabelski, Eur. Phys. J. C26, 81, 2002, and hep-ph/0103337

Figure 1: QGSM diagrams describing secondary baryon B production by diquark d: (a) initial SJ together with two valence quarks and one sea quark, (b) together with one valence quark and two sea quarks, and (c) together with three sea quarks.



Fragmentation Functions ⇓ ⇓ ⇓

$$G \sim \Big[v_{qq} \cdot (a) + v_q \cdot (b) + v_0 \cdot (c)\Big] \cdot z^{\beta}$$

$$(a)\ G^B_{qq}(z) = a_N \cdot v_{qq} \cdot z^{2.5} ,$$

$$(b)\ G^B_{qs}(z) = a_N \cdot v_{qs} \cdot z^2(1-z) ,$$

$$(c)\ G^B_{ss}(z) = a_N \cdot \varepsilon \cdot v_{ss} \cdot z^{1-\alpha_{SJ}}(1-z)^2 ,$$

where a_N is the normalization parameter, and v_{qq}, v_{qs}, v_{ss} are the relative probabilities for different baryons production.

The first two diagrams in Fig. 1 can not contribute to the inclusive spectra in the central region, but the third contribution is essential if the value of the intercept of the SJ exchange Regge-trajectory, α_{SJ}, is to be large enough.

The contribution of the graph in Fig. 1c has a coefficient ε which determines the small probability of such baryon number transfer to occur.

At high energies the SJ contribution to the inclusive cross section of secondary baryon production at large rapidity distance Δy from the incident nucleon can be estimated as

$$(1/\sigma)d\sigma^B/dy \sim \varepsilon \cdot e^{(1-\alpha_{SJ})\Delta y} \; ,$$

that reduces the number of leading baryons.

The QGSM predictions for the inclusive spectra of secondary protons and neutrons at energies $\sqrt{s} = 900$ GeV, and 100 TeV are presented in Figs. 2 and 3.

In all these calculations we have accounted for the exact conservation of the baryon charge.

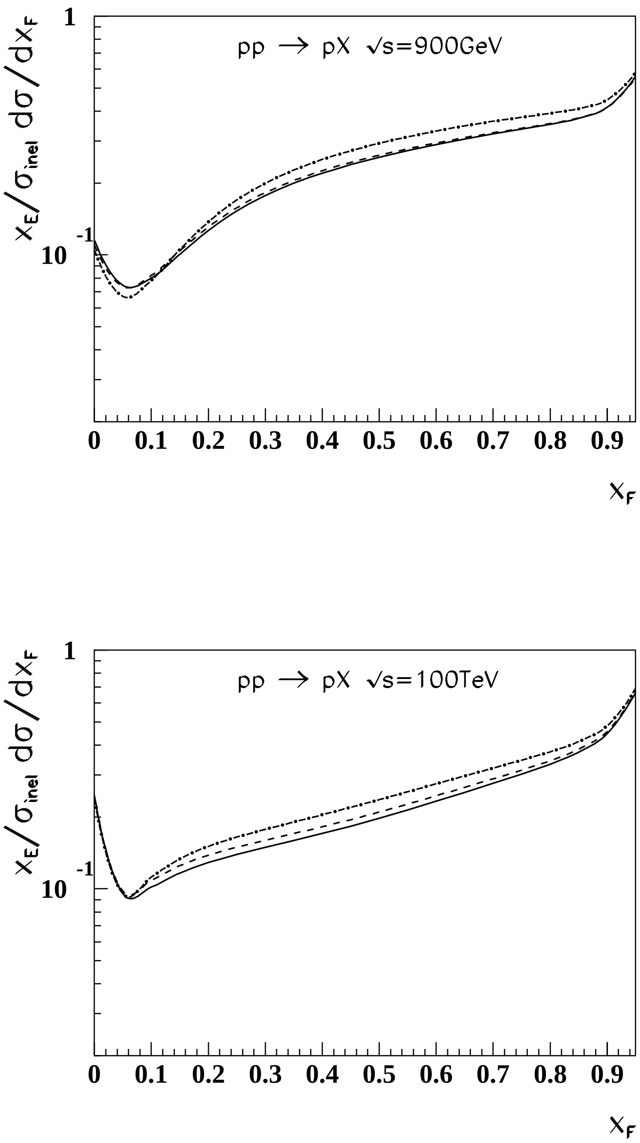


Figure 2: The QGSM predictions for the spectra of secondary protons at energies $\sqrt{s} = 900$ GeV (up), and $\sqrt{s} = 100$ TeV (down). Solid curves correspond to the value $\alpha_{SJ} = 0.9$, dashed curves to the value $\alpha_{SJ} = 0.5$, and dash-dotted curves are calculated without SJ contribution.

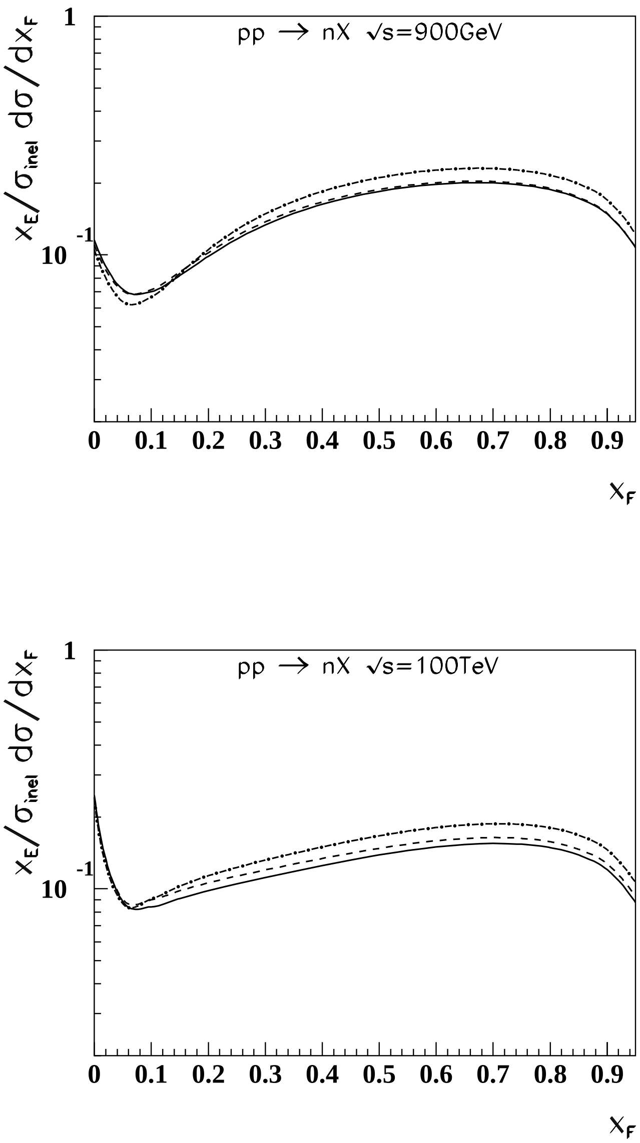


Figure 3: The QGSM predictions for the spectra of secondary neutrons at energies $\sqrt{s} = 900$ GeV (up), and $\sqrt{s} = 100$ TeV (down). Solid curves correspond to the value $\alpha_{SJ} = 0.9$, dashed curves to the value $\alpha_{SJ} = 0.5$, and dash-dotted curves are calculated without SJ contribution.

The preliminary calculations by the LHCf Collaboration show different results for the two models (Sybill and QCSJET2)

⟶ Though Sybill predicts scaling over the LHC energies, a Monte Carlo based on QCSJET2 predicts the softening of the spectrum at high energies.

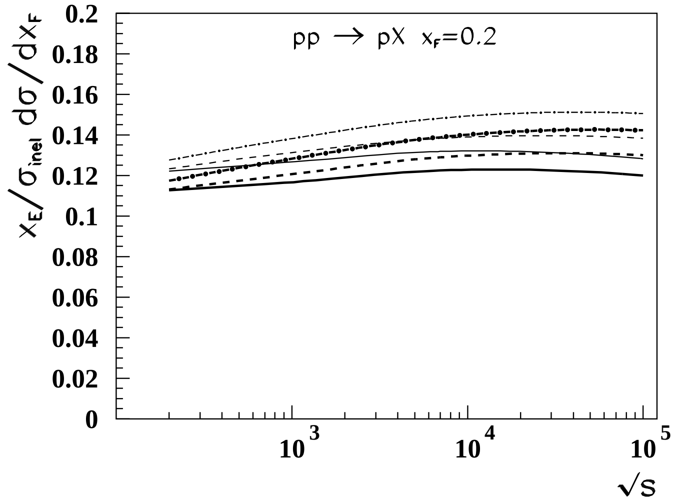
T. Sako, LHCf Collaboration, hep-ex/1010.0195
M. Bongi. LHCf Collaboration, report on CRLHC Workshop, 29th November 2010, Trento, Italy
O. Adriani et al. LHCf Collaboration, arXiv:1012.1490 [hep-ex]

Our calculations predict smaller Feynman scaling violation than in the QCSJET2 prediction, but larger than those of the Sybill predictions.

The possible Feynman scaling violation at superhigh energies was also discussed in the MC QGSM by

J.Bleibel, L.V.Bravina, A.B.Kaidalov and E.E.Zabrodin, arXiv:1011.2703 [hep-ph]

Our results are close to this prediction.



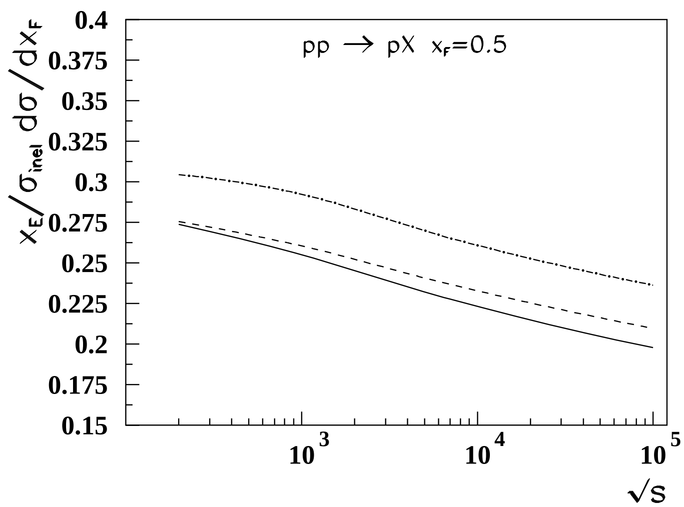


Figure 4: The QGSM predictions for the spectra of secondary protons as function of the energy at fixed values of x_F. Thin curves show the total proton spectra and bold curves - the spectra of net protons, i.e. the values of $p - \bar{p}$ differences. Solid curves correspond to the value $\alpha_{SJ} = 0.9$, dashed curves to the value $\alpha_{SJ} = 0.5$, and dash-dotted curves are calculated without SJ contribution.

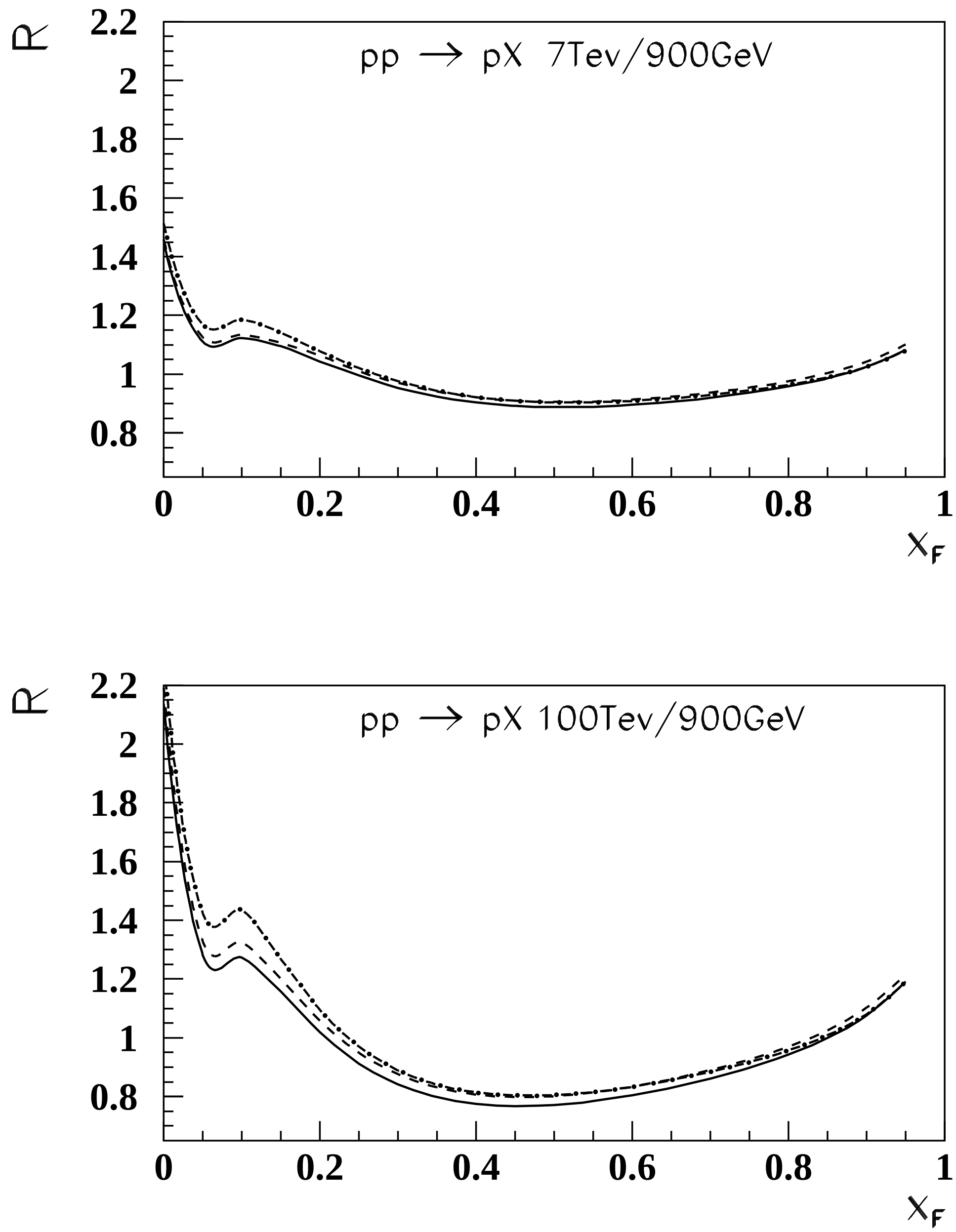


Figure 5: The QGSM predictions for the ratios of the spectra of secondary protons at energies $\sqrt{s} = 7$ TeV and $\sqrt{s} = 100$ TeV to $\sqrt{s} = 900$ GeV.

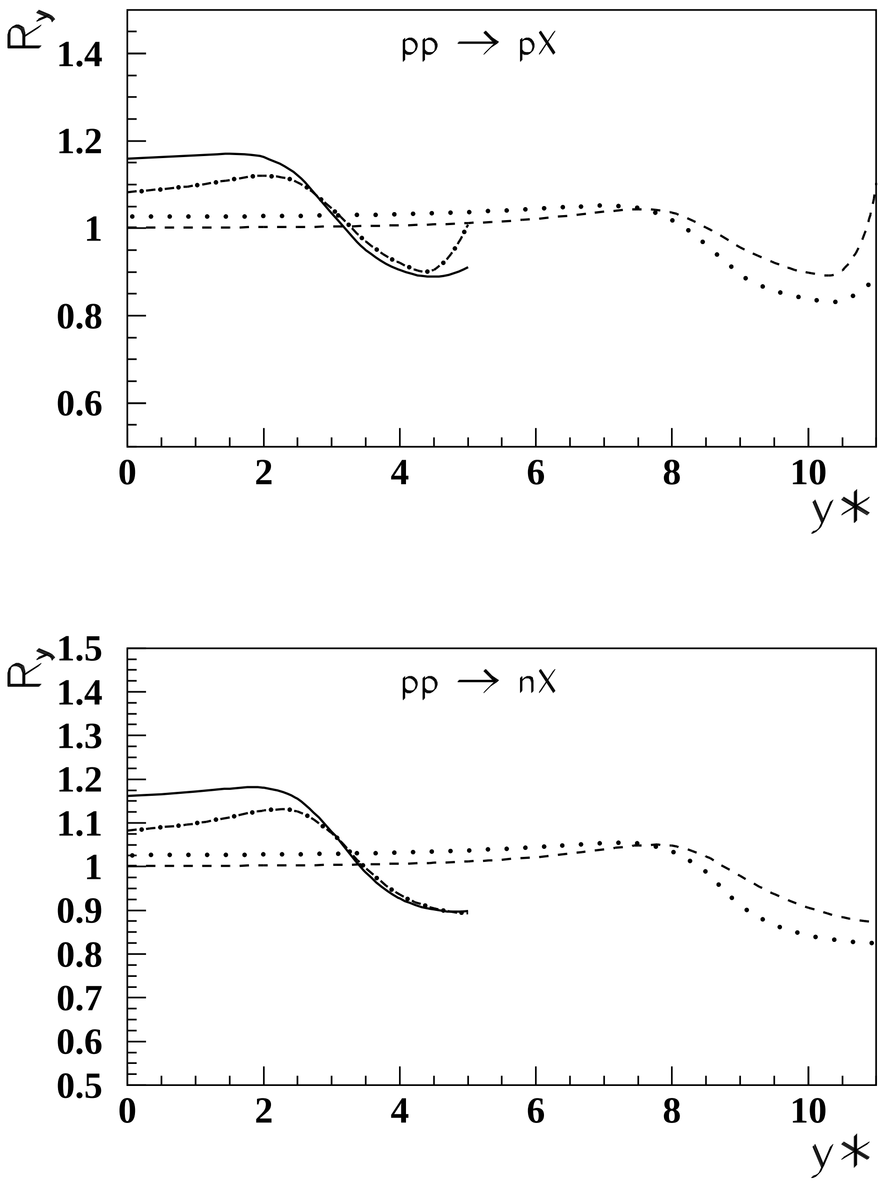


Figure 6: The QGSM predictions for y^* dependence of ratios of the spectra of secondary protons and neutrons calculated with different α_{SJ} to the spectra without SJ. The solid curve correponds to the ratio of cross sections with $\alpha_{SJ} = 0.9$ to the cross section without SJ at $\sqrt{s} = 200$ GeV. The dashed curve - is the same ration at $\sqrt{s} = 100$ TeV. The dash-dotted curve corresponding to the ratio with $\alpha_{SJ} = 0.5$ and without SJ at $\sqrt{s} = 200$ GeV and dotted curve correspond to the same ration at $\sqrt{s} = 100$ TeV.

Conclusions

- We present the QGSM predictions for Feynman scaling violation in the spectra of leading baryons due to baryon charge diffusion at large distances in the rapidity space.

- Both for secondary protons and neutrons we have the Feynman scaling violation in the region $x_F = 0.5 - 0.8$ is of about 7 - 10% for $\sqrt{s} = 200$ GeV and 900 GeV, and it becomes of about 15 - 20% at $\sqrt{s} = 7$ TeV and 100 TeV.