b, $b\bar{b}$ and $b\gamma$ production at Tevatron in the Regge limit of QCD

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1. Particle production in the quasi-multi-Regge kinematics
2. Effective vertices in the QMRK approach
3. Inclusive b and $b\bar{b}$ production at Tevatron
4. Associated $b + \gamma$ production at Tevatron
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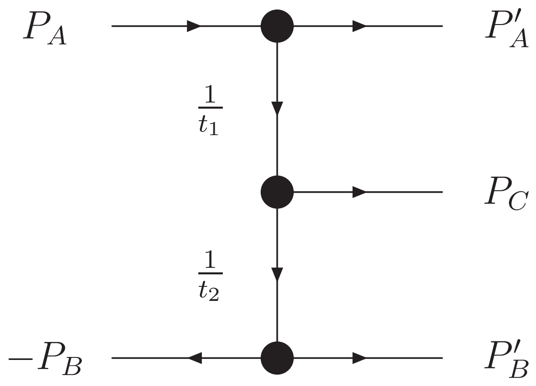
Particle production in the quasi-multi-Regge kinematics



$$S_{AB} = (P_A + P_B)^2, \quad S_{A'C} = (P_{A'} + P_C)^2, \quad S_{B'C} = (P_{B'} + P_C)^2$$

$$S_{A'C},\ S_{B'C}, P_C^2\ , P_{TC}^2\ \ll S_{AB}, \quad (P_A \cdot P_{A'}) \ll (P_A \cdot P_C) \ll (P_A \cdot P_{B'})$$

$$y_{A'} \gg y_C \gg y_{B'}$$

Electron Reggeization in QED:

M. Gell-Mann, M. L. Goldberger, F. E. Low, E. Marx, and F. Zachariasen, **1964**.

Quark Reggeization in QCD:

V. S. Fadin and V. E. Sherman, **1976**

Qluon Reggeization in QCD:

E. A. Kuraev, L. N. Lipatov, and V. S. Fadin, **1975**
I. I. Balitsky and L. N. Lipatov, **1978**

$$P_1 = E_1(1,0,0,1), \qquad P_2 = E_2(1,0,0,-1), \qquad S = 4E_1E_2$$

$$(n^+)^\mu = P_2^\mu/E_2, \qquad (n^-)^\mu = P_1^\mu/E_1, \qquad k^\pm = k \cdot n^\pm = k^\mu n_\mu^\pm$$

$$q_1 = x_1P_1 + q_{1T}, \qquad q_2 = x_2P_2 + q_{2T}, \qquad t_1 = -q_1^2 = -q_{1T}^2, \qquad t_2 = -q_2^2 = -q_{2T}^2$$

Vertex functions:

$$g(k) + Q(q) \to q(k+q): \qquad \gamma_\mu^{\pm}(q,k) = \gamma_\mu + \hat{q}\frac{n^{\pm}}{k^{\pm}},$$

$$Q(q_1) + \bar{Q}(q_2) \to g(q_1+q_2): \qquad \gamma_\mu^{+-}(q_1,q_2) = \gamma_\mu - \frac{\hat{q}_1 n_\mu^-}{q_2^-} - \frac{\hat{q}_2 n_\mu^+}{q_1^+}$$

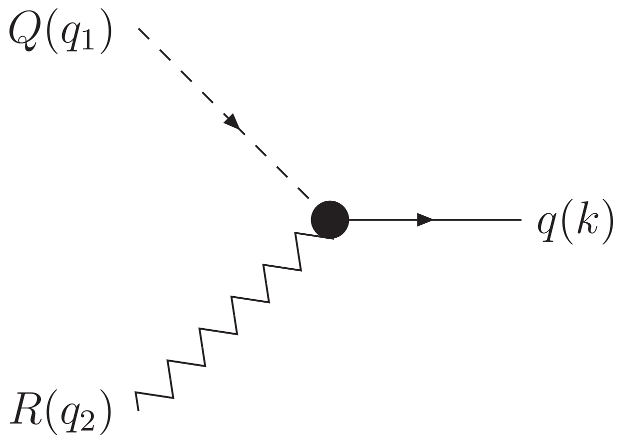
Effective vertices for b and $b\bar{b}$ production

The QMRK approach is based on effective quantum field theory implemented with the non-Abelian gauge-invariant action:

Reggeized gluons (R), L. N. Lipatov, **1995**,
Reggeized quarks (Q), L. N. Lipatov and M. I. Vyazovsky, **2001**

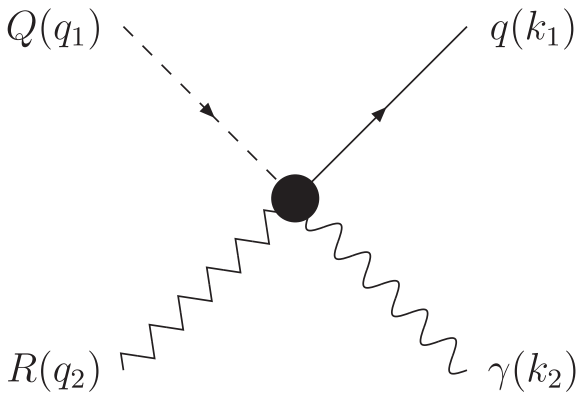
Feynman rules for the effective theory:

E. N. Antonov, L. N. Lipatov, E. A. Kuraev, and I. O. Cherednikov, **2005**
L. N. Lipatov and M. I. Vyazovsky, **2001**



$$C^{RQ\to q}(q_1,q_2) = -ig_sT^a\gamma_\mu^{(-)}(q_1,q_2)\Pi_T^{(+)\mu}(q_2), \qquad q=b$$

$$\Pi_T^{(+)\mu}(q_2) = \frac{q_{2T}^\mu}{|\vec{q}_{2T}|}, \qquad \Pi_T^{(+)\mu}(q_2) = -\frac{x_2E_2(n^+)^\mu}{|\vec{q}_{2T}|}.$$



$$C_\mu^{RQ\to\gamma q}(q_1,q_2,k_1,k_2) = -ee_q g_s T^b \Pi_T^{(+)\nu}(q_2)\Big[\gamma_\nu \frac{\hat{q}_1-\hat{k}_2}{(q_1-k_2)^2}\gamma_\mu^{(-)}(-k_2,q_1)+$$

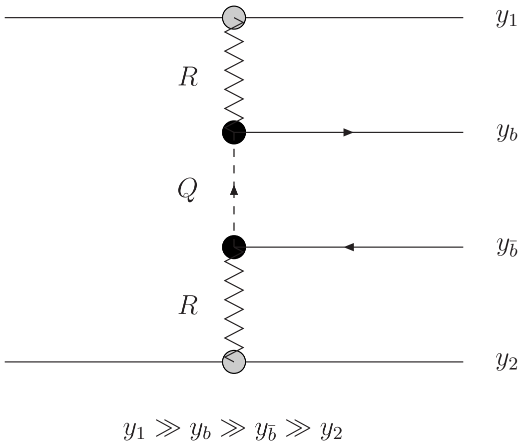
$$\gamma_\mu \frac{\hat{k}_1+\hat{k}_2}{(k_1+k_2)^2}\gamma_\nu^{(-)}(q_2,q_1) - \hat{q}_1\frac{n_\mu^- n_\nu^-}{q_2^- k_2^-}\Big]$$

$$d\sigma(p\bar{p} \to X) = \sum_{i,j} \int \frac{dx_1}{x_1} \int \frac{d^2 q_{1T}}{\pi} \int \frac{dx_2}{x_2} \int \frac{d^2 q_{2T}}{\pi} \Phi_i^p(x_1, t_1, \mu^2) \Phi_j^{\bar{p}}(x_2, t_2, \mu^2) d\hat{\sigma}(ij \to X)$$

$$d\hat{\sigma}(ij \to X) = \frac{1}{2x_1 x_2 S} \times \overline{|\mathcal{M}(ij \to X)|^2} \times d\Phi_X$$

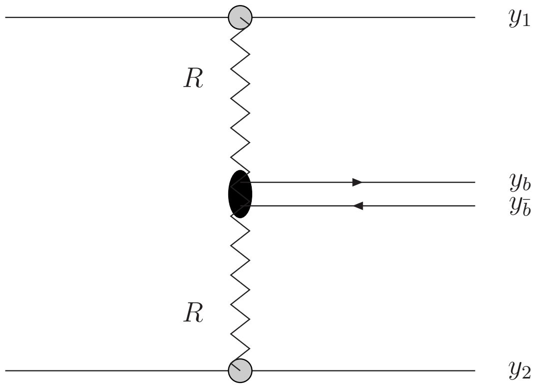
At the stage of numerical calculations we use the Kimber-Martin-Ryskin (KMR) prescription for unintegrated quark and gluon distribution functions $\Phi_{q,g}^{\gamma,p}(x, |\mathbf{q}_T|^2, \mu^2)$, with the Martin-Roberts-Stirling-Thorne (MRST) collinear densities as input.

$b\bar{b}$–jet production in the multi-Regge kinematics



$$\mathcal{A}^{MRK} \sim \Gamma^{R}_{PP} \times \left(\frac{s_1}{t_1}\right)^{\omega(t_1)} \times \Gamma^{b}_{RQ} \times \left(\frac{s}{t}\right)^{\omega(t)} \times \Gamma^{\bar{b}}_{QR} \times \left(\frac{s_2}{t_2}\right)^{\omega(t_2)} \times \Gamma^{R}_{PP}$$

$b\bar{b}$–jet production in the quasi-multi-Regge kinematics

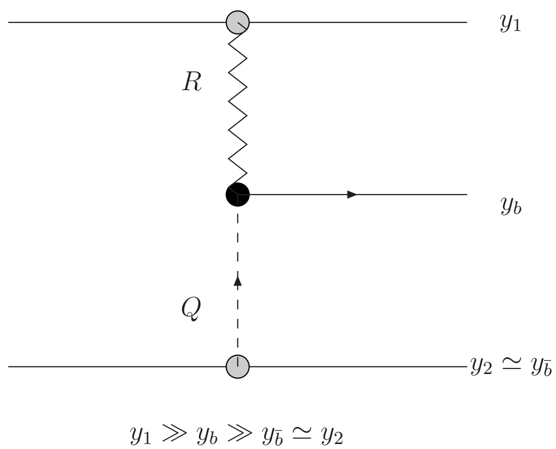


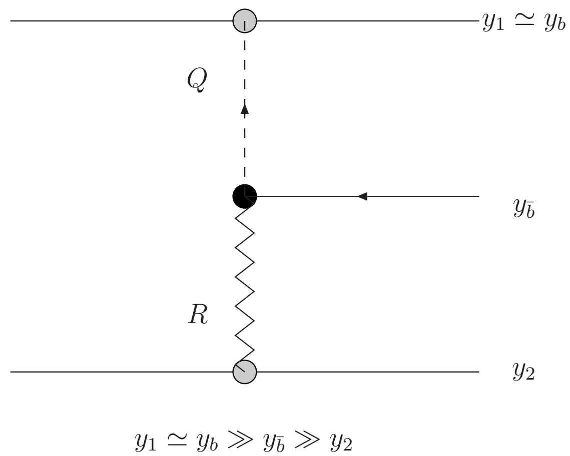
$y_1 \gg y_b \simeq y_{\bar{b}} \gg y_2$

$$\mathcal{A}^{QMRK} \sim \Gamma^{R}_{PP} \times \left(\frac{s_1}{t_1}\right)^{\omega(s_1)} \times \Gamma^{b\bar{b}}_{RR} \times \left(\frac{s_2}{t_2}\right)^{\omega(t_2)} \times \Gamma^{R}_{PP}$$

$$\sigma(PP \to b\bar{b}X) = \Phi_R \otimes \hat{\sigma}(RR \to b\bar{b}) \otimes \Phi_R$$

$b-$jet production in the multi-Regge kinematics





$$\mathcal{A}^{QMRK} \sim \Gamma^{Q}_{PP} \times \left(\frac{s_1}{t_1}\right)^{\omega(t_1)} \times \Gamma^{b}_{QR} \times \left(\frac{s_2}{t_2}\right)^{\omega(t_2)} \times \Gamma^{R}_{PP}$$

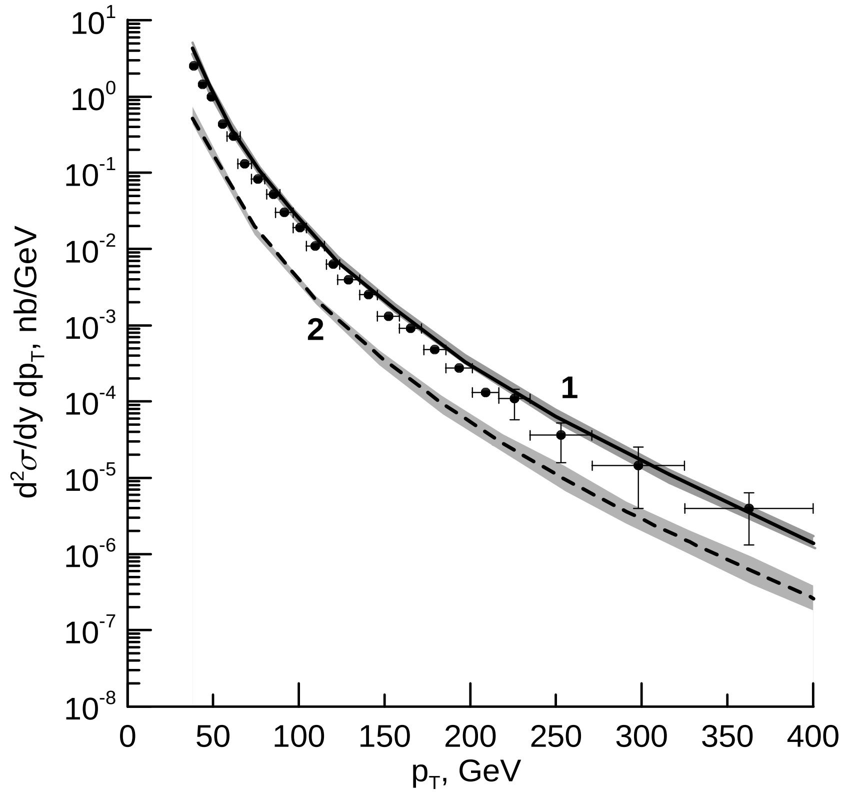
$$\sigma(PP \to bX) = \Phi_Q \otimes \hat{\sigma}(Q_b R \to b) \otimes \Phi_R$$

Inclusive $b-$jet production at Tevatron

$$\sqrt{S} = 1.96 \text{ GeV}, \qquad |y_b| < 0.7, \quad |y_{\bar{b}}| < 4.5,$$

$$R_{cone} = \sqrt{(y_b - y_{\bar{b}})^2 - (\phi_b - \phi_{\bar{b}})^2} > 0.4$$

CDF note 8418, 2006, URL: `http://www-cdf.fnal.gov/physics/new/qcd/QCD.html`



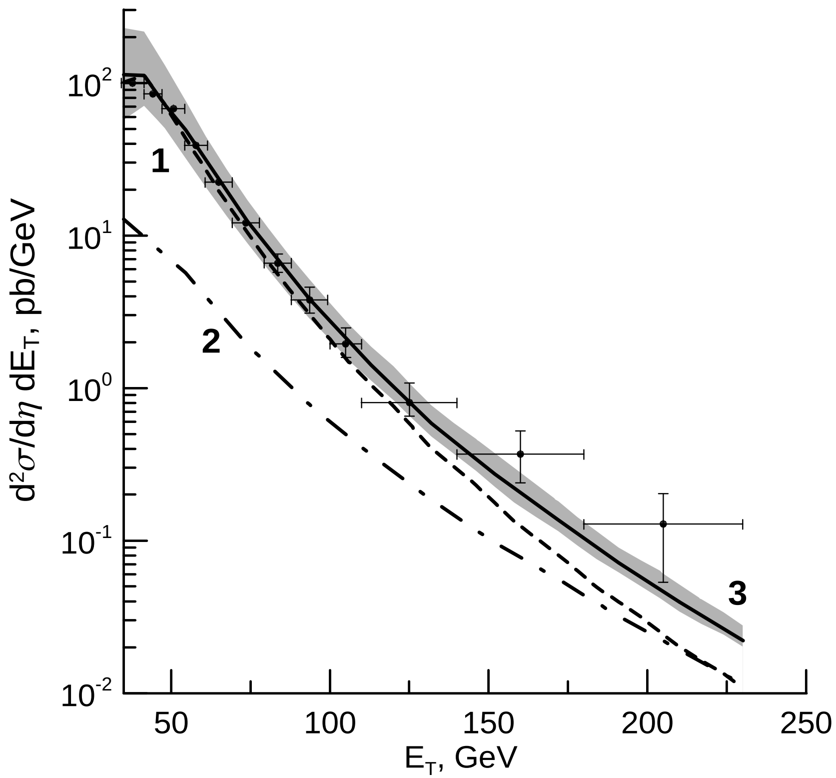
$$1 \text{ - } RQ_b \to b,\ 2 \text{ - } RR \to b\bar{b}$$

Associated $b\bar{b}$–jet production at Tevatron

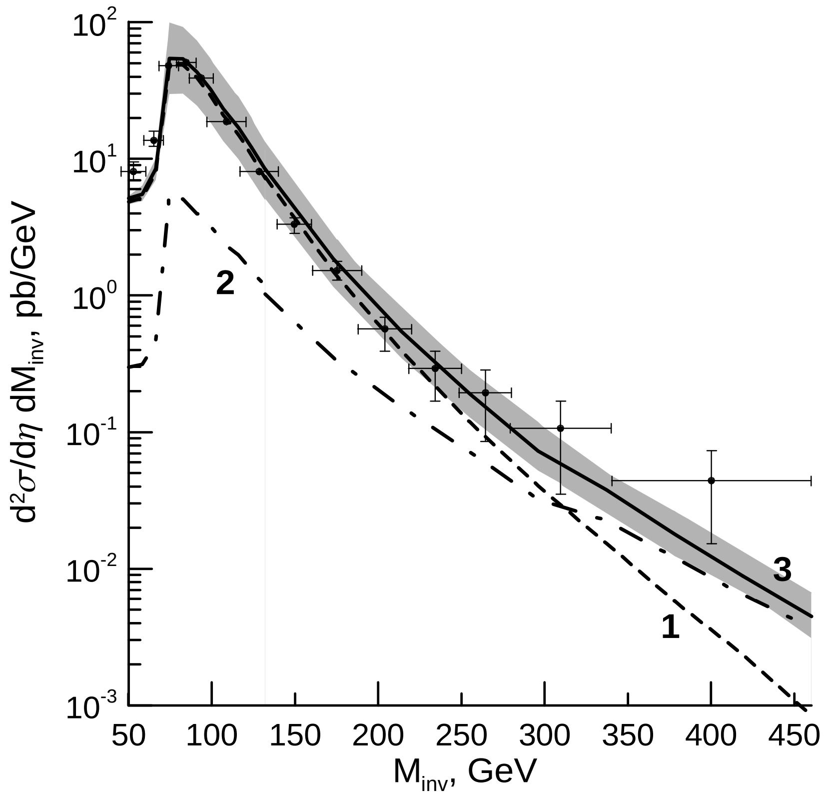
$$\sqrt{S} = 1.96 \text{ GeV}, \qquad |y_{b\bar{b}}| < 1.2,\ E_{bT} > 35 \text{ GeV},\ E_{\bar{b}T} > 32 \text{ GeV},$$

$$R_{cone} = \sqrt{(y_b - y_{\bar{b}})^2 - (\phi_b - \phi_{\bar{b}})^2} > 0.4$$

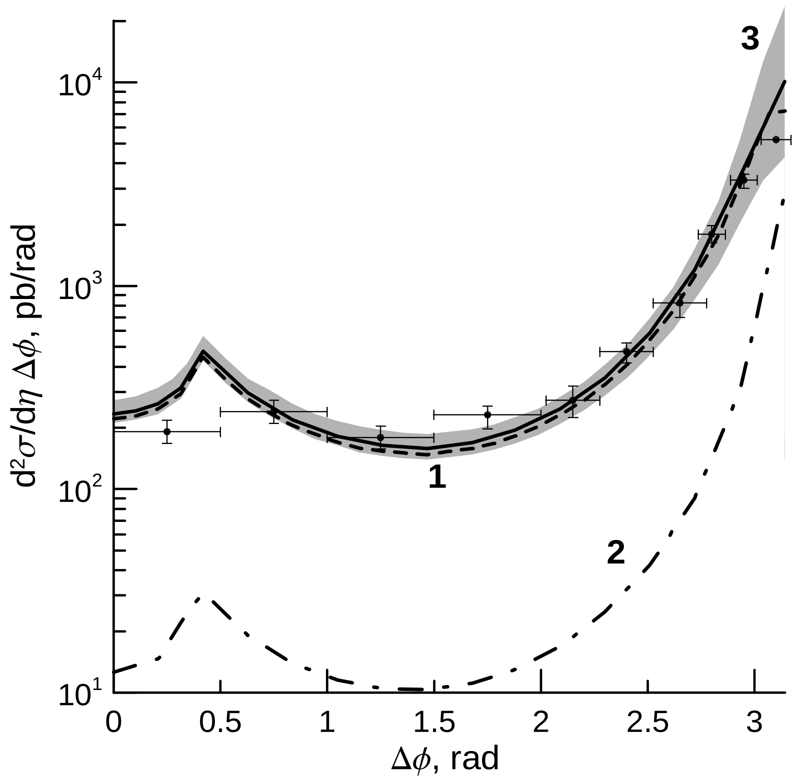
CDF note 8939, 2007, URL: `http://www-cdf.fnal.gov/physics/new/qcd/QCD.html`.



$$1 \text{ - } RR \to b\bar{b},\ 2 \text{ - } Q\bar{Q} \to b\bar{b},\ 3 \text{ - } 1{+}2$$



1 - $RR \to b\bar{b}$, 2 - $Q\bar{Q} \to b\bar{b}$, 3 - $1{+}2$



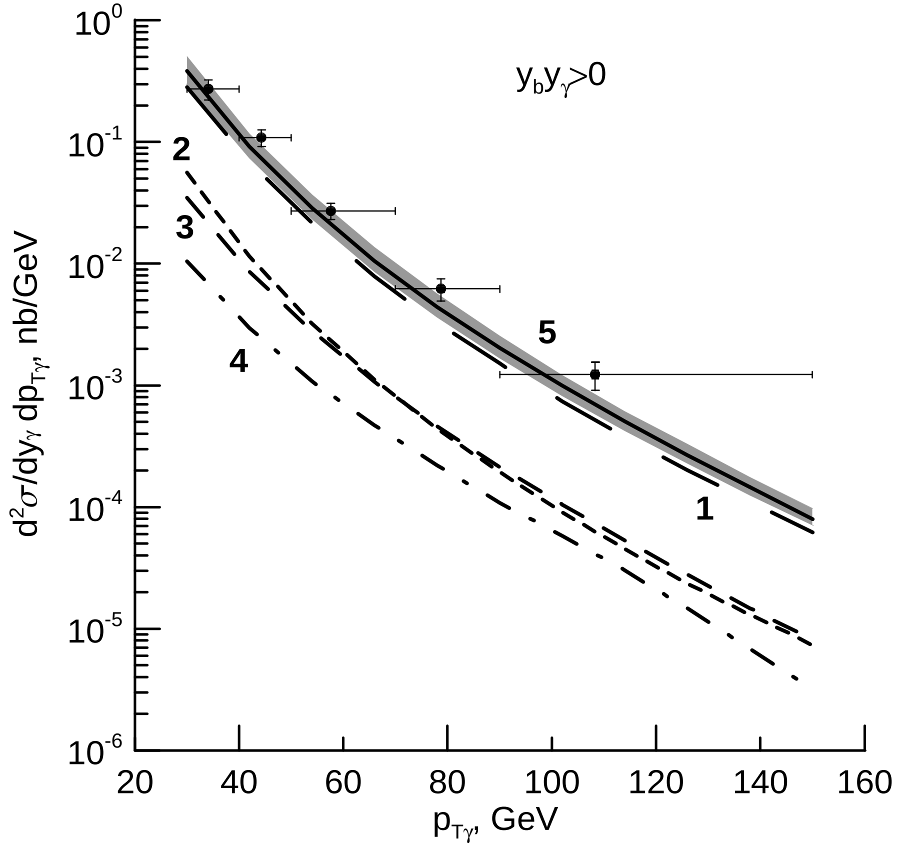
1 - $RR \to b\bar{b}$, 2 - $Q\bar{Q} \to b\bar{b}$, 3 - 1+2

Associated $b\gamma$ production at Tevatron

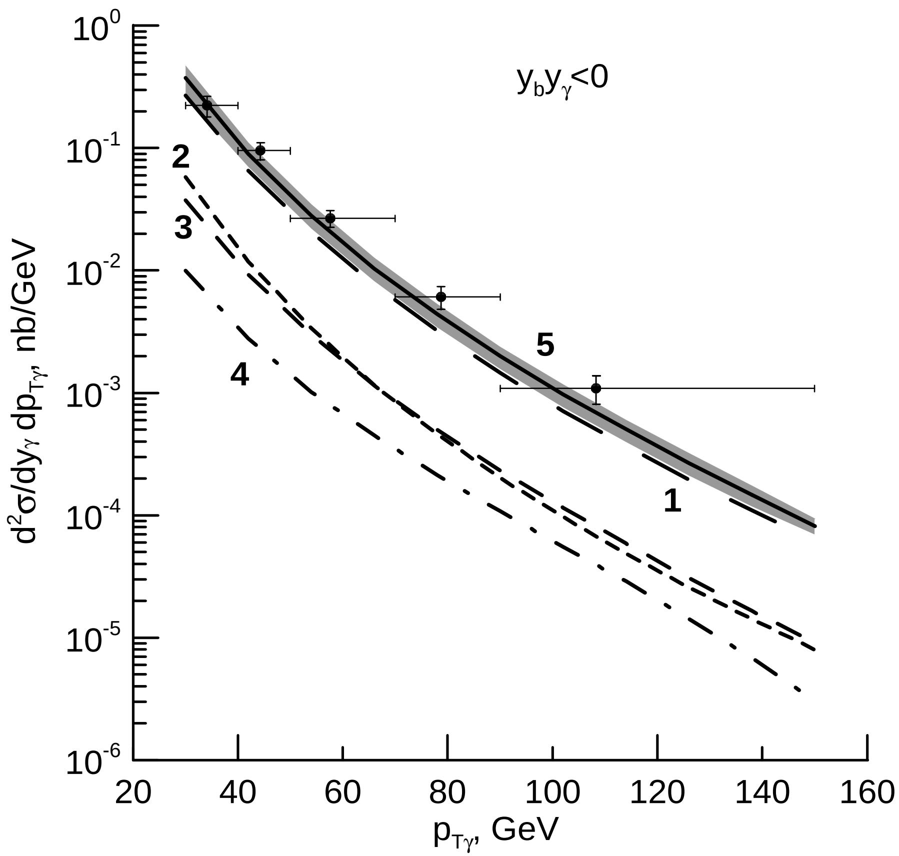
$$\sqrt{S} = 1.96 \text{ GeV}, \qquad |y_\gamma| < 1.0, \qquad |y_b| < 0.8,$$
$$30 < E_{T\gamma} < 150 \text{ GeV}, \ E_{Tb} > 15 \text{ GeV},$$

$$R_{cone} = \sqrt{(y_b - y_\gamma)^2 - (\phi_b - \phi_\gamma)^2} > 0.7$$

D0 Collaboration, Phys. Rev. Lett. **102**, 192002 (2009).



1 - $RQ_b \to b\gamma$, 2 - $RR \to b\bar{b}(\gamma)$, 3 - $QQ_b \to bq(\gamma)$, 4 - $QQ \to bb(\gamma)$, 5 - sum



1 - $RQ_b \to b\gamma$, 2 - $RR \to b\bar{b}(\gamma)$, 3 - $QQ_b \to bq(\gamma)$, 4 - $QQ \to bb(\gamma)$, 5 - sum

Conclusion

We studied the inclusive hadroproduction of single b jets, $b\bar{b}$ dijets and $b\gamma$ dijets at LO in the QMRK approach with Reggeized partons in the initial state. Despite the great simplicity of our formulas, our theoretical predictions turned out to describe recent measurements of various cross section distributions by the CDF and D0 Colaborations in Run II at the Tevatron surprisingly well, without any ad-hoc adjustments of input parameters. By contrast, in the collinear parton model of QCD, such a degree of agreement can only be achieved by taking NLO corrections into account and performing soft-gluon resummation.

The QMRK approach is once again (*) proven to be a powerful tool for the theoretical description of QCD processes in the high-energy limit.

(*)

1. **Charmonium production:** B. A. Kniehl, D. V. Vasin, and V. A. Saleev, Phys. Rev. D **73**, 074022 (2006) [arXiv:hep-ph/0602179];

2. **Botomonium production:** B. A. Kniehl, V. A. Saleev and D. V. Vasin, Phys. Rev. D **74**, 014024 (2006) [arXiv:hep-ph/0607254];

3. *D* **meson production:** B. A. Kniehl, A. V. Shipilova, and V. A. Saleev, Phys. Rev. D **79**, 034007 (2009) [arXiv:0812.3376 [hep-ph]];

4. **Direct photon production:** V. A. Saleev, Phys. Rev. D **78**, 034033 (2008) [arXiv:0807.1587 [hep-ph]]; V. A. Saleev, Phys. Rev. D **78**, 114031 (2008) [arXiv:0812.0946 [hep-ph]].