# Diffractive Production of Heavy Flavors

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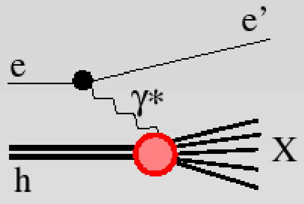
Ivan Schmidt

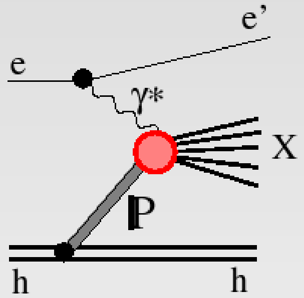
# QCD factorization in Diffraction

## Ingelman-Schlein picture of diffraction.

DIS on a proton (inclusive $\gamma^* + p \to X$) provides the distribution of partons in the proton.




Therefore, DIS on the Pomeron (diffraction $\gamma^* + p \to X + p$) provides the distribution of partons in the Pomeron.



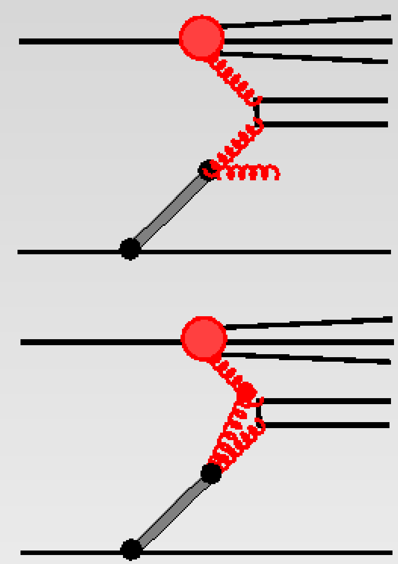

Once the parton densities in the Pomeron are known, one can predict the cross section of any hard hadronic reaction.
For instance (A.Donnachie & P.Landshoff),

$$\sigma_{sd}^{DY}(pp \to \bar{l}l\, X\, p) = G_{I\!P/p} \otimes F_{\bar{q}/I\!P} \otimes F_{q/p} \otimes \hat{\sigma}(\bar{q}q \to \bar{l}l).$$

# QCD factorization in Diffraction

## Breakdown of factorization.

This naive picture fails due to compositeness of the Pomeron (J.Collins, L.Frankfurt & M.Strikman). The usual assumption that only one parton participates in the hard interaction, while other partons in the hadron are spectators, apparently is not correct for the Pomeron which may interact as a whole.

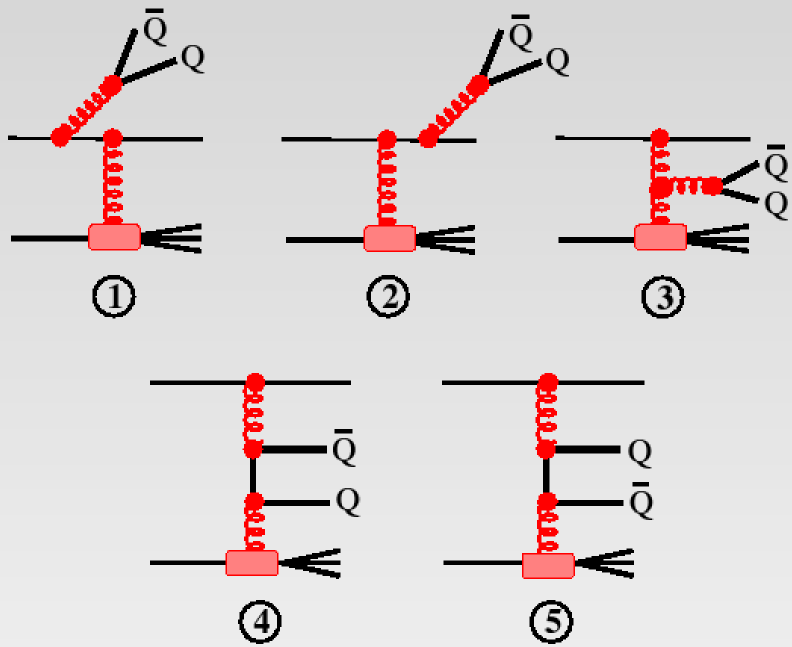


The full calculation of relevant graphs (F.Yuan & K.-T.Chao) misses, however, the interaction with the spectator partons which leads to:

- Dependence of hard diffraction on the hadronic size;
- Leading twist behavior, $1/Q^4 \Rightarrow 1/Q^2$.

# Heavy Flavors

Bremsstrahlung and Production mechanisms in inclusive production of heavy flavors by a projectile parton (quark or gluon)




$$M_{Br} = M_1 + M_2 + \frac{Q^2}{M^2 + Q^2} M_3$$

$$M_{Pr} = \frac{M^2}{M^2 + Q^2} M_3 + M_4 + M_5$$

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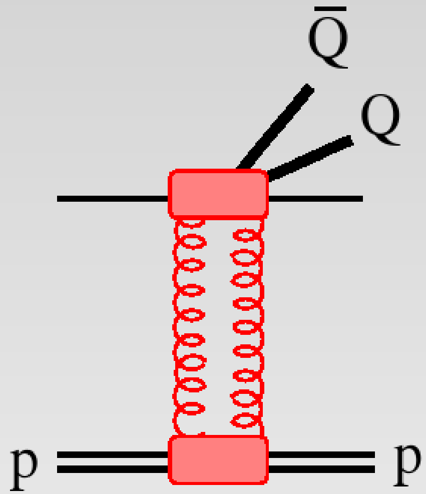
# Diffractive Heavy Flavors

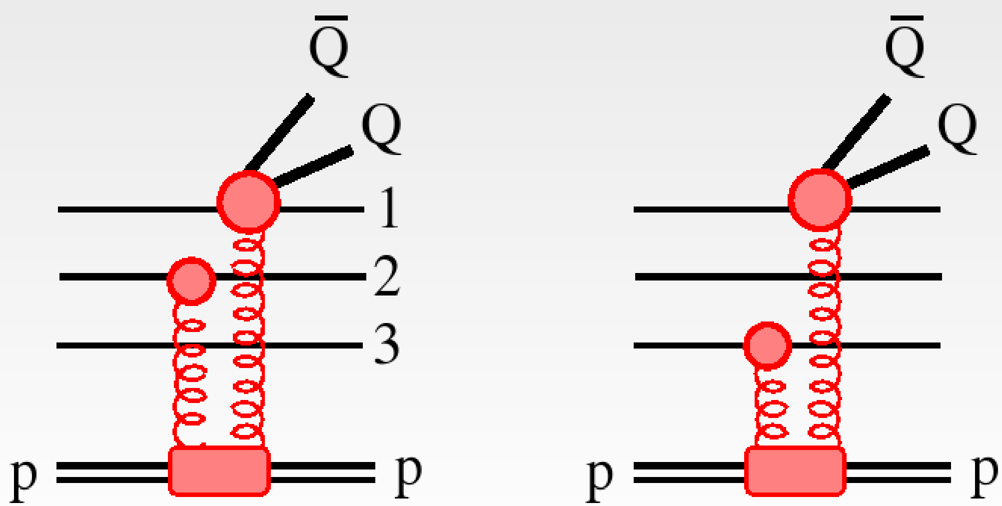
Higher twist bremsstrahlung mechanism in diffraction: radiation of a $\bar{Q}Q$ pair by an isolated parton.




$\sigma \sim 1/m_Q^4$

**Higher twist**

Leading twist bremsstrahlung mechanism in diffraction:

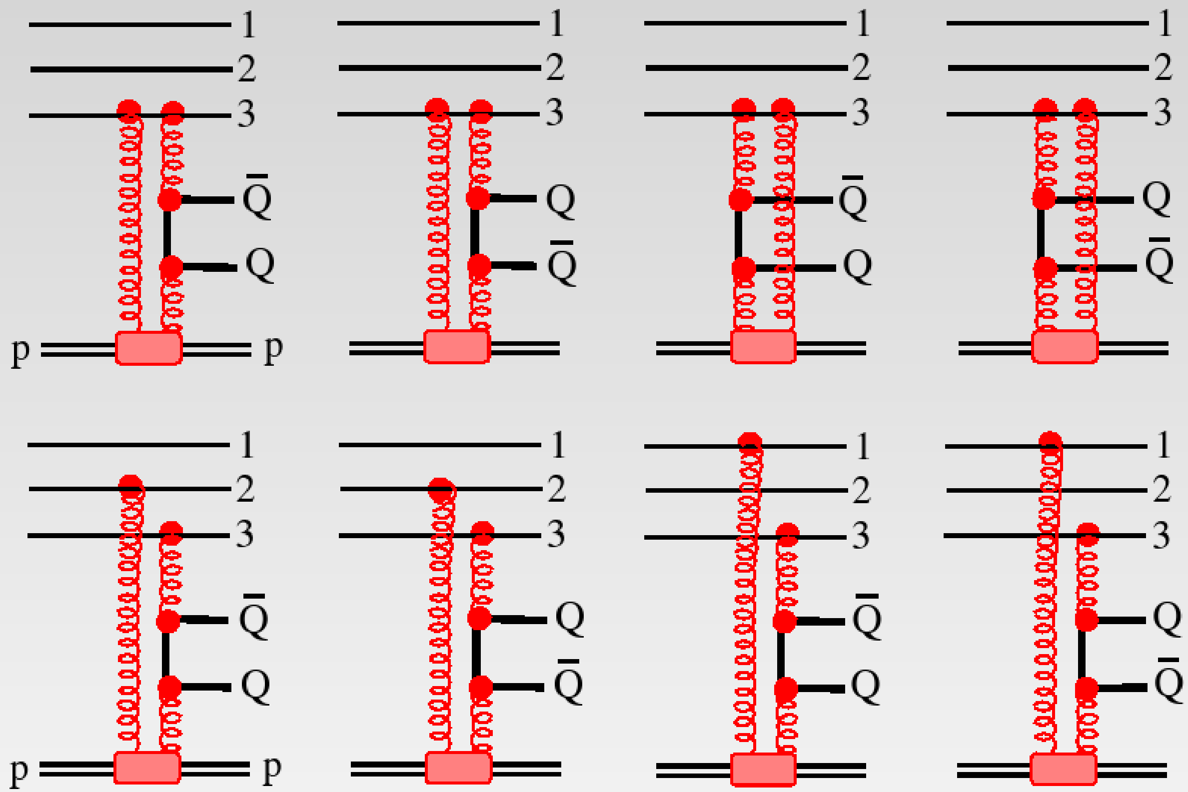



$\sigma \sim 1/m_Q^2$

**Leading twist**

# Diffractive Heavy Flavors

Production mechanism in diffraction:




$$\sigma \propto 1/m_Q^2$$

Leading twist

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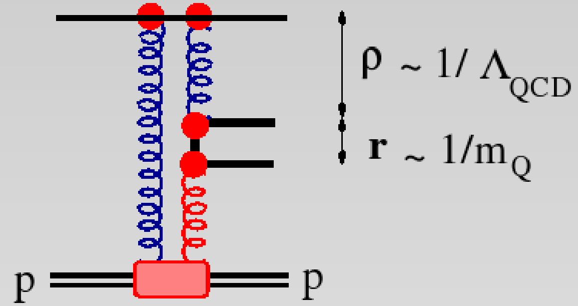
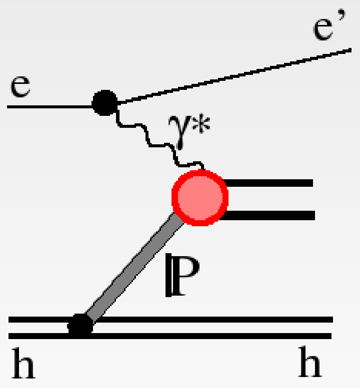
# Diffractive Heavy Flavors

Previous calculations missed the leading twist contribution $\sigma \propto 1/m_Q^2$, resulting from interaction with spectator partons.




The distance between the spectator parton and the heavy pair is large, $\vec{\rho} \sim 1/\Lambda_{QCD}$, while the the $\bar{Q}Q$ separation is very small $r \sim 1/m_Q$. Thus, two gluons (blue) in the figure are soft, and only one (red) is hard. The leading twist behavior results from interference of the two sizes.

Similar situation occurs in heavy flavor production in diffractive DIS: the heavy quarks are created far away from the electron.



# Data

- Measurements at ISR led to an amazingly large (probably incorrect) cross section of diffractive charm production (K.L.Giboni et al. 1979), $\boldsymbol{\sigma \sim 10 - 60\,\mu}$b. This experiment was order of magnitude above the subsequent data for inclusive charm production.

- The E653 experiment found no diffractive charm in $p - Si$ collisions at $800\,$GeV. There is almost no $A$-dependence between hydrogen and silicon, so $\boldsymbol{\sigma \leq 26\,\mu}$b

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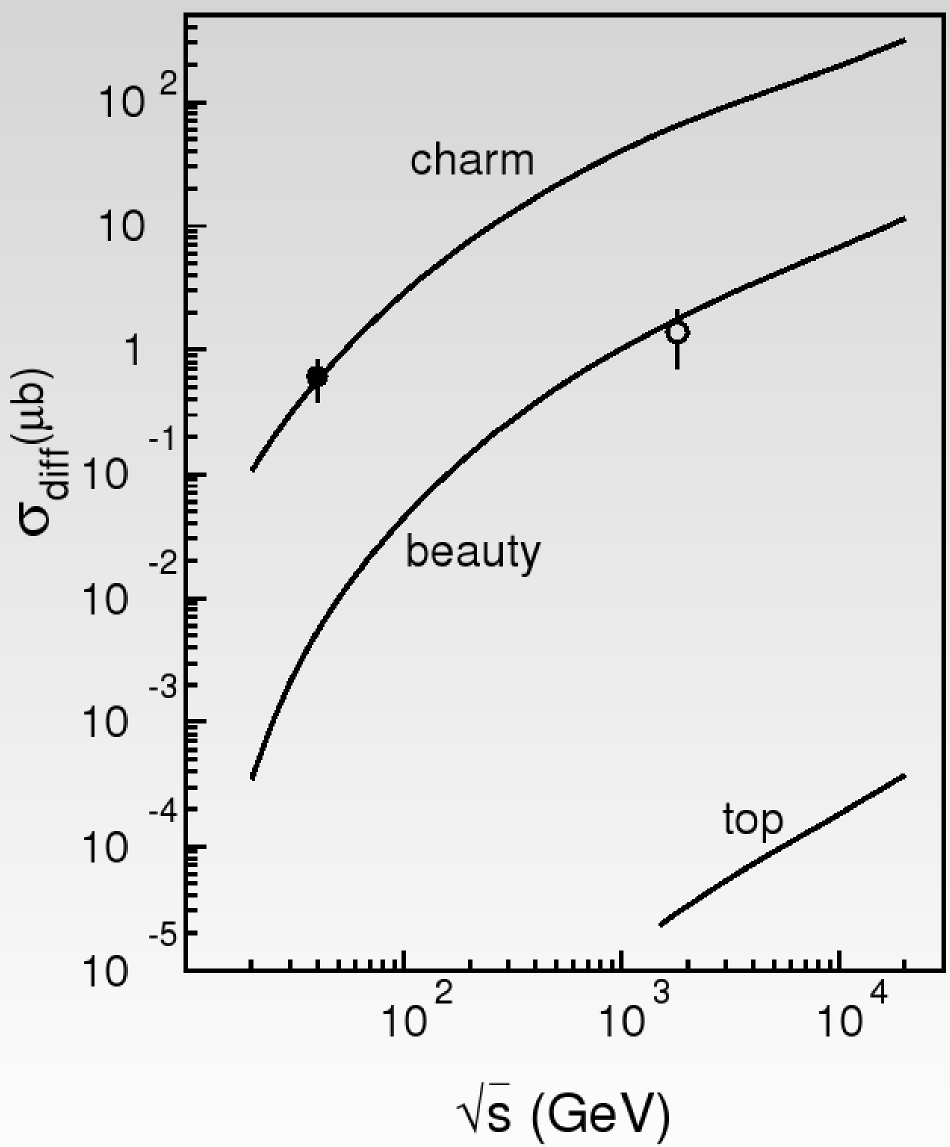
- The E690 experiment reported the diffractive charm cross section at $\boldsymbol{\sigma} = \mathbf{0.61 \pm 0.12 \pm 0.11}\ \boldsymbol{\mu}$b at $800\,$GeV. Agrees well with our calculations.

# Data

- The CDF experiment measured the fraction of diffractively produced beauty, at approximately $R^{\bar{b}b}_{diff/tot} = (1 \pm 0.5)\%$, at $\sqrt{s} = 1.8\,\mathrm{TeV}$. The total cross section of beauty production at this energy has not been measured so far. If to rely on the theoretical prediction based on dipole model calculations, $\sigma^{\bar{b}b}_{tot} = 140\,\mathrm{mb}$, then $\sigma^{\bar{b}b}_{diff} \approx 1.4 \pm 0.7\,\mathrm{mb}$. This estimate agrees rather well with our results, but contradicts by an order of magnitude the higher twist mass dependence $\sigma^{\bar{b}b}_{diff} \propto 1/m_Q^4$.

# Results

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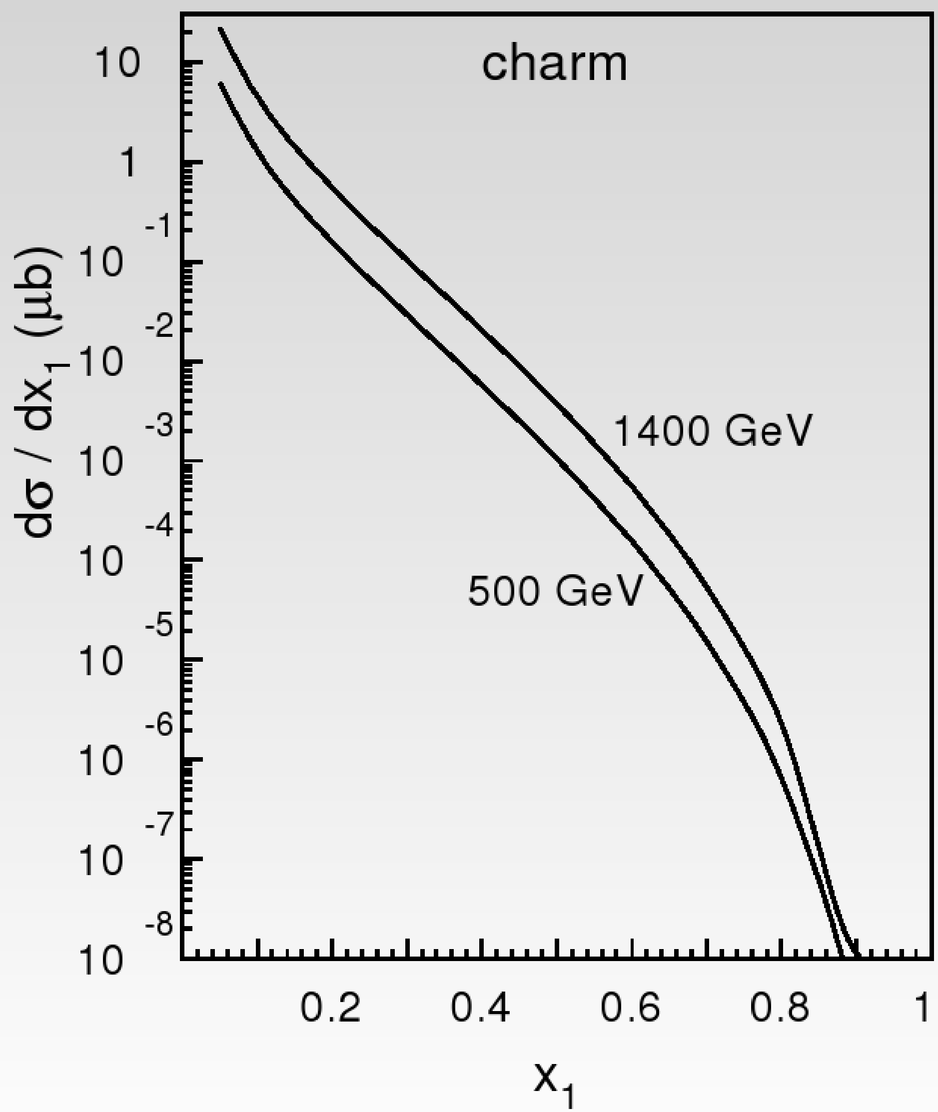
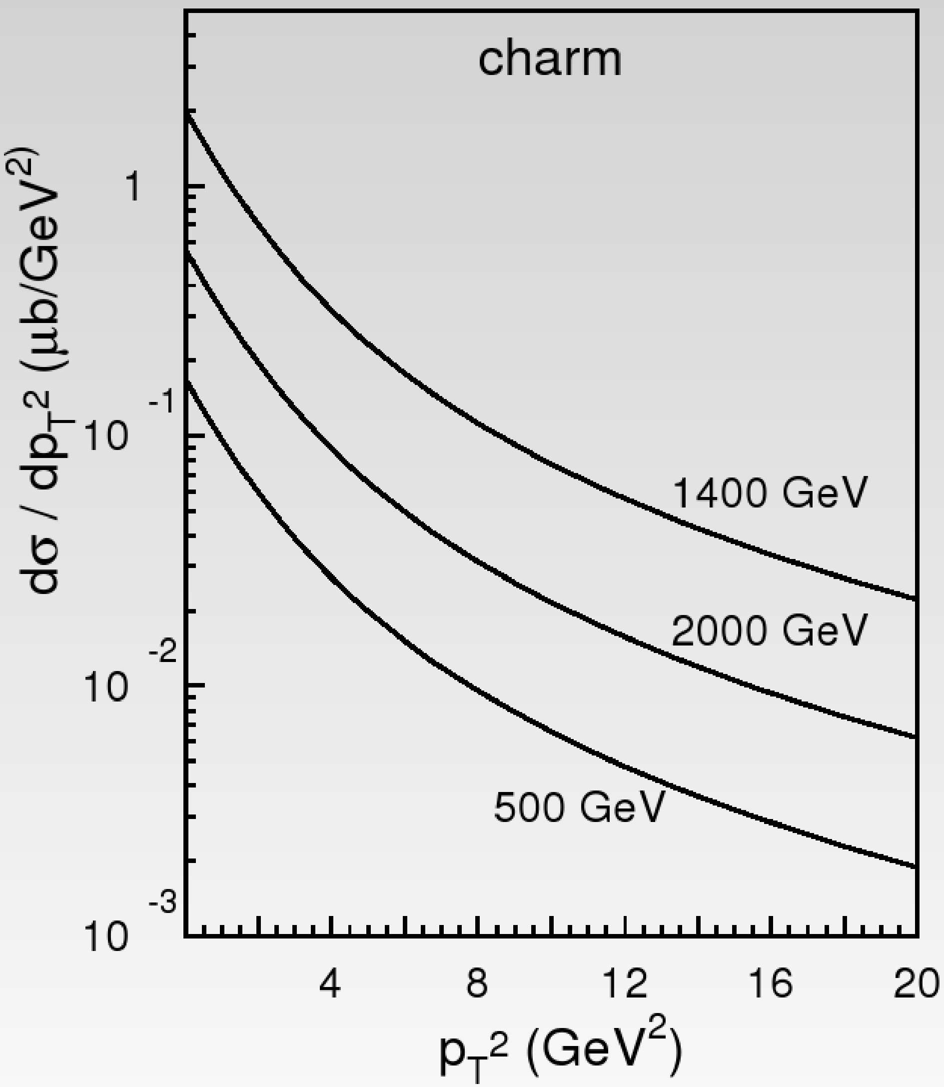
# Results




$$x_1 = p_c^+ / p_p^+$$

# Results

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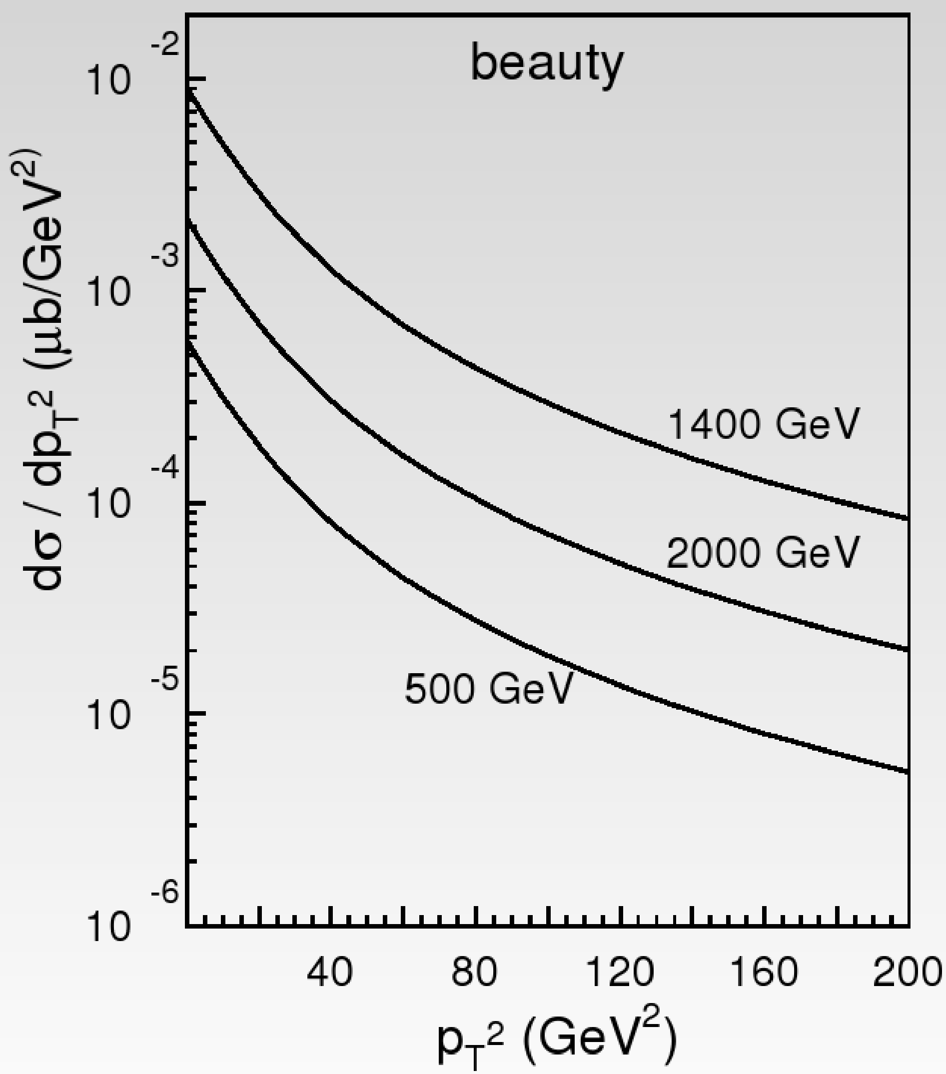


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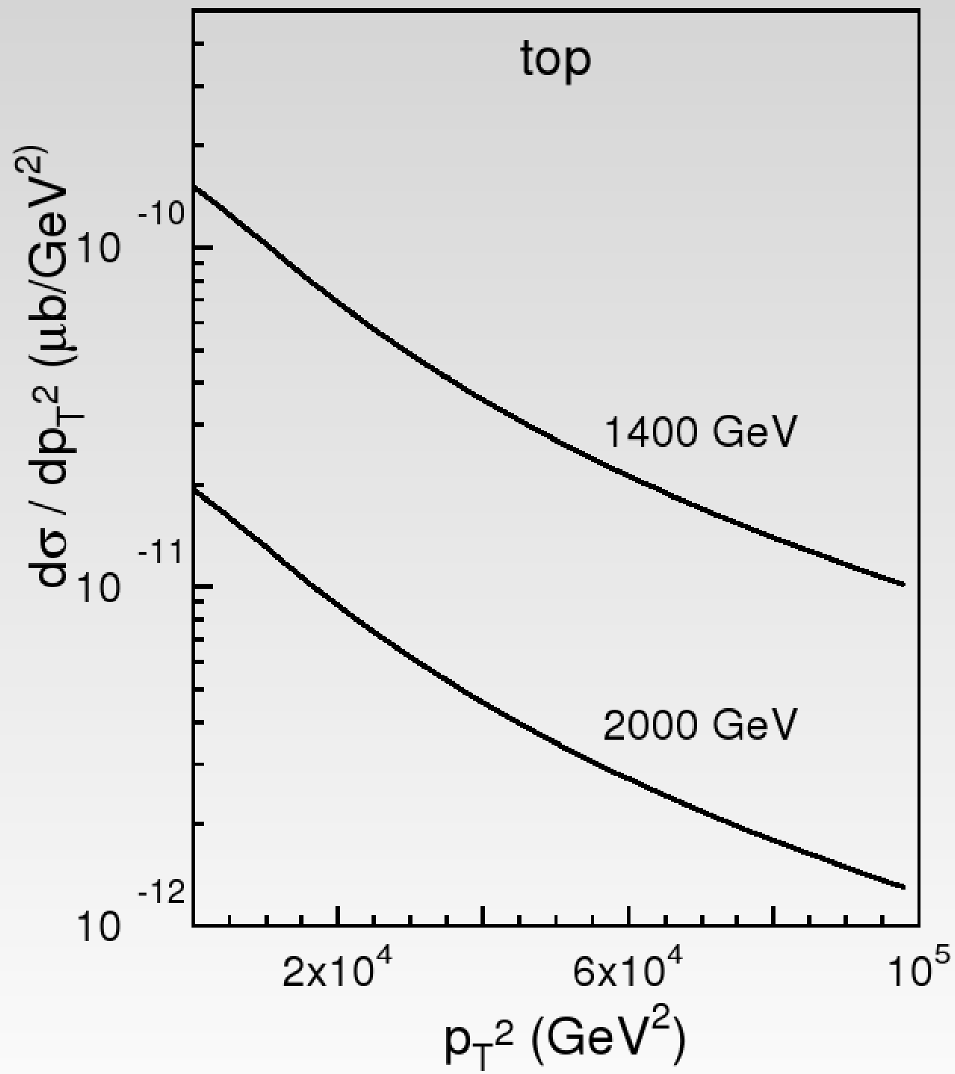


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# pA collisions

$$\sigma^{pA}_{sd}(pA \to X\bar{Q}QA) = A_{eff}\,\sigma^{pp}_{sd}(pA \to X\bar{Q}Qp)$$

$$A_{eff} = 16\pi B_{sd} \int d^2b\, T^2_A(b)\, \left\langle e^{-\sigma(r_i)T_A(b)/2} \right\rangle^2_{r_i}$$

$$B_{sd} = 12\,\mathrm{GeV}^{-2}$$

$$\boxed{A_{eff} \approx 10.}$$

# Conclusions

- Novel leading twist mechanism of heavy flavor diffractive production.
- Factorization broken.
- Two mechanisms identified: bremsstrahlung and production.
- Interaction with spectators is important.
- Available data agree with our calculations.
- Straightforward application to high-pt jets.