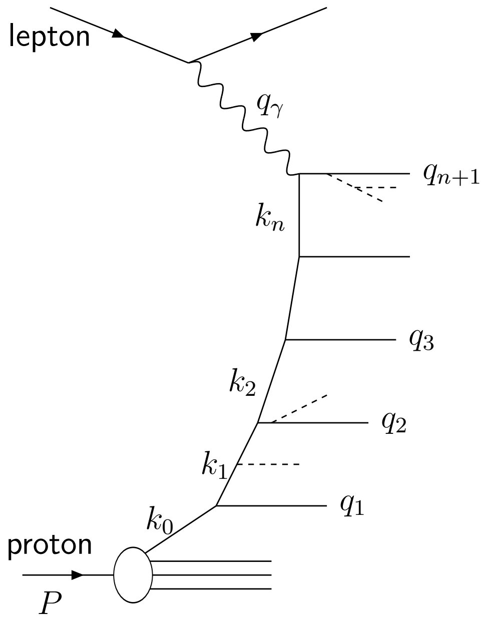
LUND UNIVERSITY

LDC uPDFs

- Linked Dipole Chain Model
- Unintegrated gluons from LDC
- Heavy quarks @ Tevatron
- Central Exclusive Higgs

Štrbské Pleso
2004.04.16
Leif Lönnblad

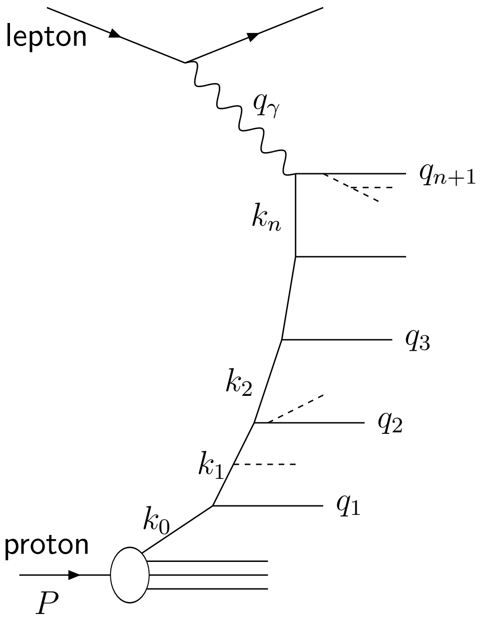
The Linked Dipole Chain Model



- Based on CCFM (but better)

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

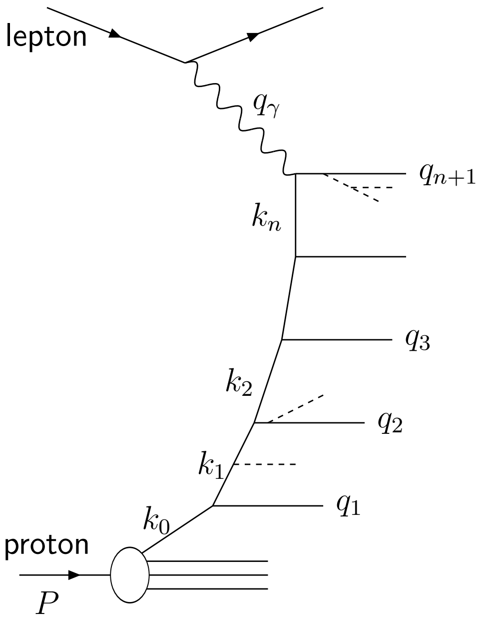
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

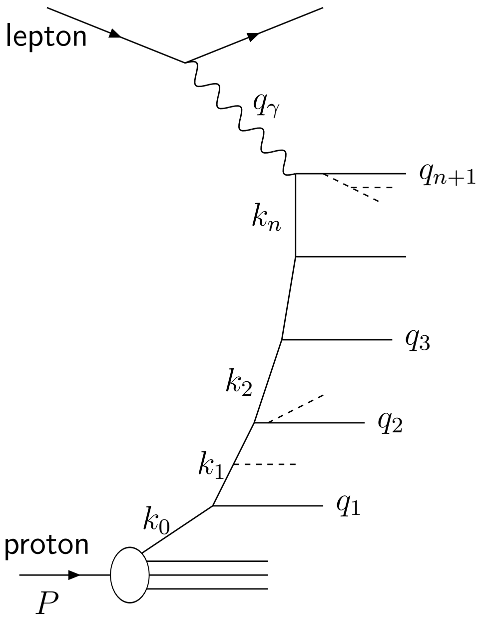
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-

$$\mathcal{G}(x,k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i)\delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i})\theta(q_{-i} - q_{-,i-1})$$

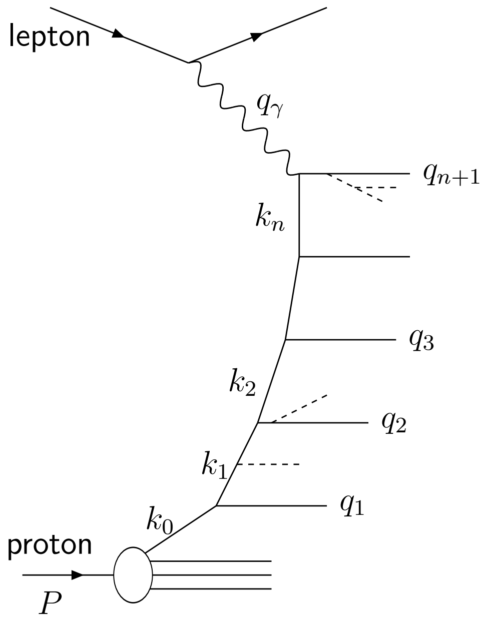
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-
- Require $q_\perp > \min(k_{\perp i-1}, k_{\perp i})$.

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times \theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

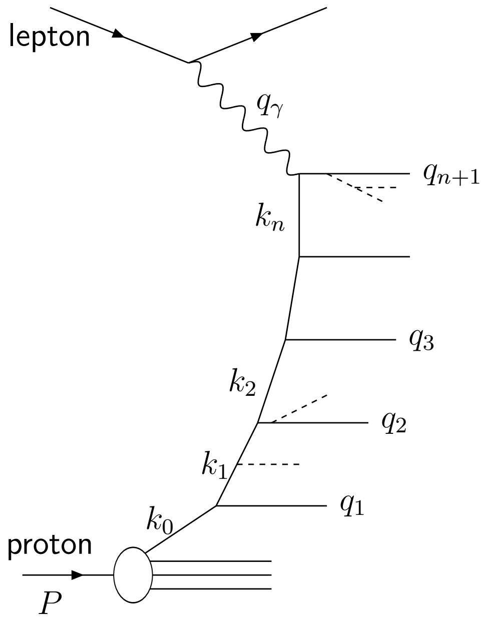
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-
- Require $q_\perp > \min(k_{\perp i-1}, k_{\perp i})$.
- No non-Sudakov

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times \theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

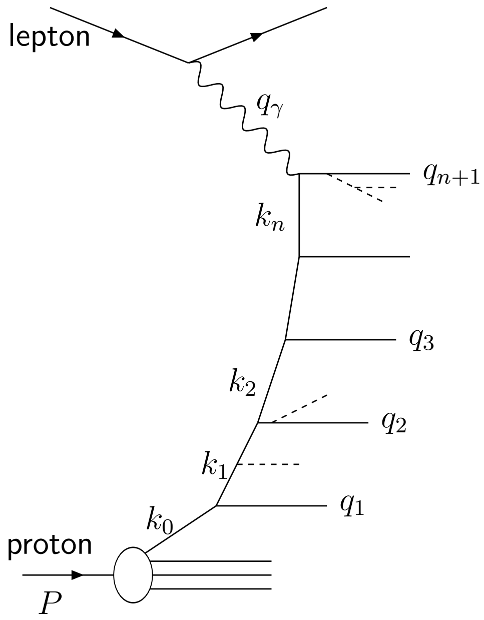
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-
- Require $q_\perp > \min(k_{\perp i-1}, k_{\perp i})$.
- No non-Sudakov
- Less infrared sensitive

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

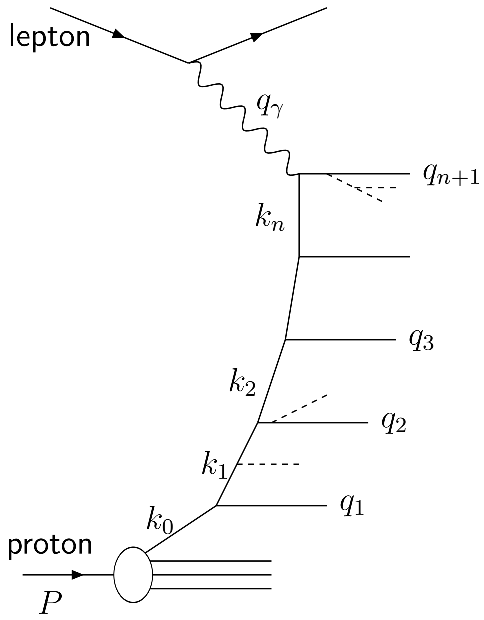
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-
- Require $q_\perp > \min(k_{\perp i-1}, k_{\perp i})$.
- No non-Sudakov
- Less infrared sensitive
- Straight forward to add quarks

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

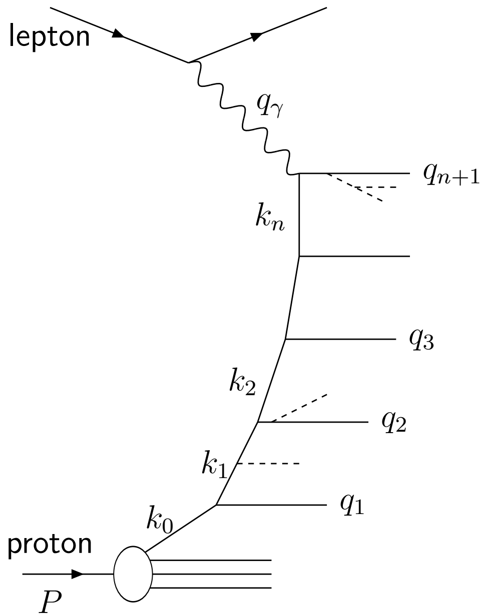
The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-
- Require $q_\perp > \min(k_{\perp i-1}, k_{\perp i})$.
- No non-Sudakov
- Less infrared sensitive
- Straight forward to add quarks
- and non-singular terms

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

The Linked Dipole Chain Model



- Based on CCFM (but better)
- Redefine initial- vs. final-state
- Order emissions in q_+ and q_-
- Require $q_\perp > \min(k_{\perp i-1}, k_{\perp i})$.
- No non-Sudakov
- Less infrared sensitive
- Straight forward to add quarks
- and non-singular terms
- Forward–backward symmetric

$$\mathcal{G}(x, k_\perp^2) \sim \sum_n \int \prod^n \bar{\alpha} dz_i \frac{d^2 q_{\perp i}}{\pi q_{\perp i}^2} P(z_i) \Delta_S \delta(x - \Pi z_i) \delta(\ln k_\perp^2 - \ln k_{\perp n}^2) \times$$
$$\theta(q_{+,i-1} - q_{+i}) \theta(q_{-i} - q_{-,i-1})$$

The fact that LDC is forward-backward symmetric enables us to construct a shower which is neither forward or backward evolution. All emissions are generated in one go in the variables $\ln q_{\pm i}$ according to a simple approximate distribution.

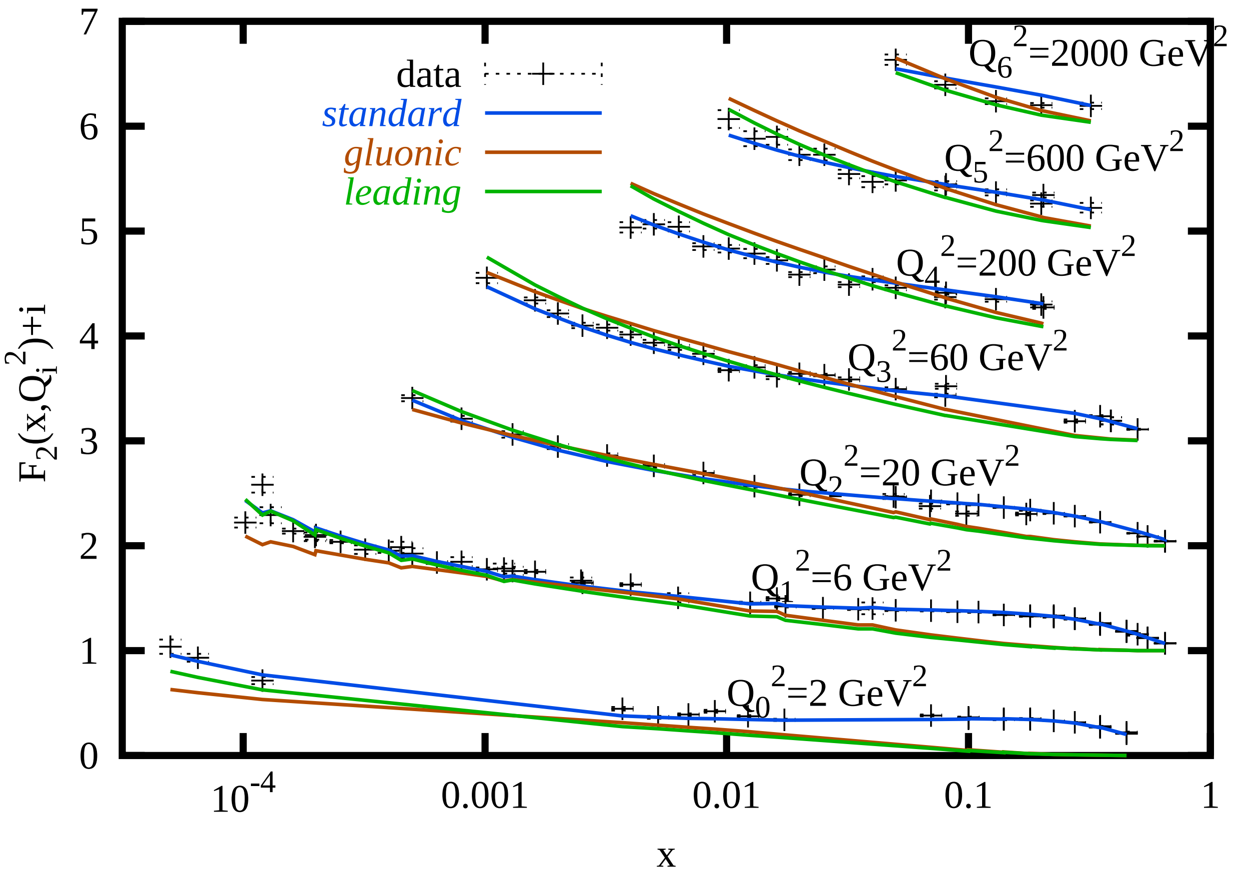
$$\sqrt{\frac{a}{b}} I_1(2\sqrt{ab}) = \sum_{n=1}^{\infty} \frac{a^n b^{n-1}}{n!(n-1)!} \int \bar{\alpha}^n \Pi_j \frac{dz_{j+}}{z_{j+}} \frac{dz_{j-}}{z_{j-}} \delta(\ln x_0/x + \Sigma_j \ln z_{j+})$$

(with $a = \sqrt{\bar{\alpha}} \ln Q^2/k_{\perp 0}^2 + b$ and $b = \sqrt{\bar{\alpha}} \ln x_0/x$)

Afterwards the the ϕ angles are generated and the exact kinematic is constructed, and each vertex is reweighted.

Also the top quark box is treated this way and $k_\perp$-factorization is not used explicitly.

The perturbative evolution is convoluted with input parton densities which are fit to F_2



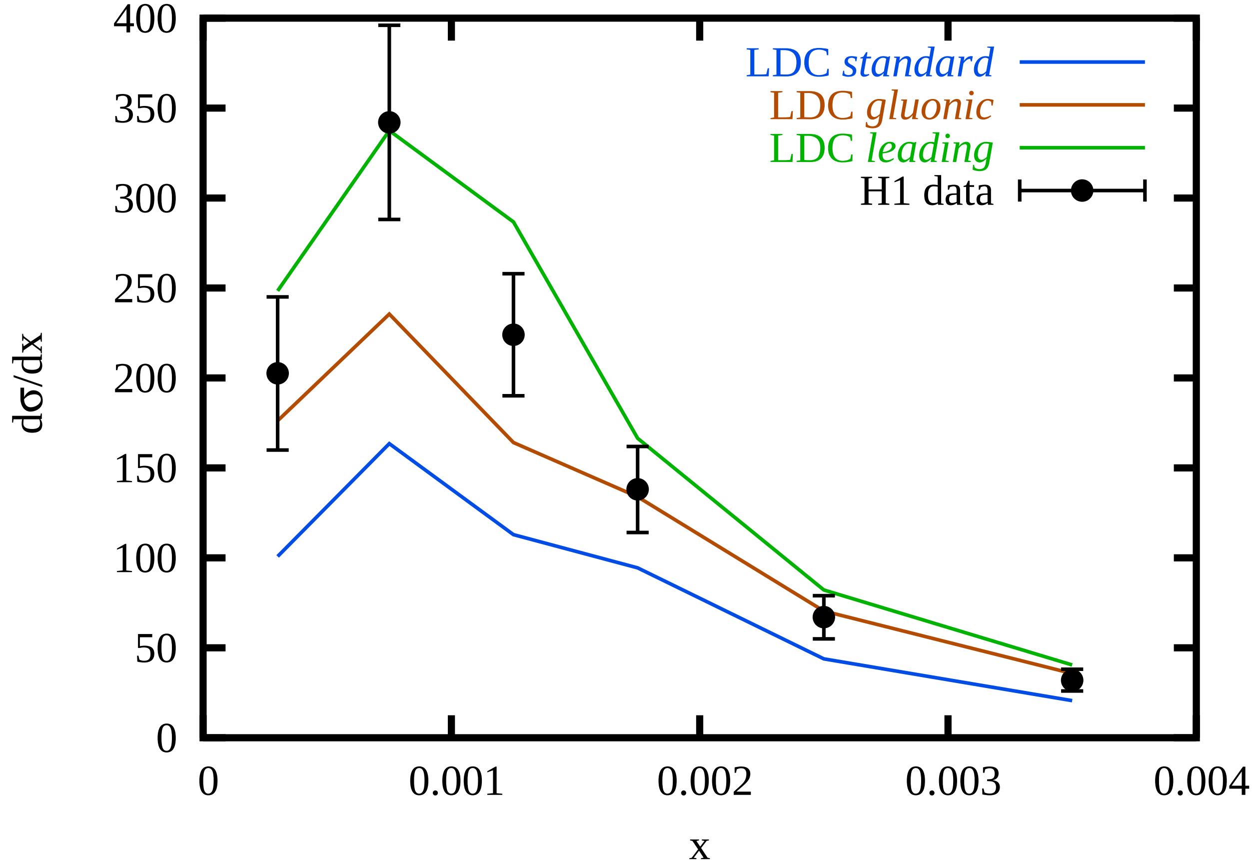
We will use three different strategies for LDC which differs in the treatment of non-leading terms.

standard uses quark and gluon evolution with full splitting functions. Gives a good description of F_2.

gluonic uses only gluons with full splitting function. Gives a good description of the integrated gluon.

leading uses only gluons with only singular terms in the splitting function. Gives a good description of forward jets and b-production at the Tevatron.

Very sensitive to the treatment of non-leading terms



H1 forward jets (1998) $p_\perp > 3.5$ GeV

The LDC unintegrated gluon

Since LDC does not explicitly use $k_\perp$-factorization, the unintegrated gluon has to be extracted by `measuring` it from a large number of generated DIS events.

What is extracted is a one-scale density, $\mathcal{G}(x, k_\perp^2)$. The second scale enters mainly in the last step from the Sudakov:

$$\mathcal{G}(x, k_\perp^2, \bar{q}^2) \approx \mathcal{G}(x, k_\perp^2)\Delta_S(k_\perp^2, \bar{q}^2)$$

The unintegrated gluon can now be used to calculate various cross section with $k_\perp$-factorization, convoluting with off-shell matrix elements. We have to take care:

- What is the scale $\bar{q}$?

- What scale to use in α_s in the off-shell ME.

- How to handle situations with $k_\perp > \bar{q}$?

The unintegrated gluon can now be used to calculate various cross section with $k_\perp$-factorization, convoluting with off-shell matrix elements. We have to take care:

- What is the scale $\bar{q}$? Determined by the rapidity of the outgoing partons in the off-shell ME.
- What scale to use in α_s in the off-shell ME.
- How to handle situations with $k_\perp > \bar{q}$?

The unintegrated gluon can now be used to calculate various cross section with $k_\perp$-factorization, convoluting with off-shell matrix elements. We have to take care:

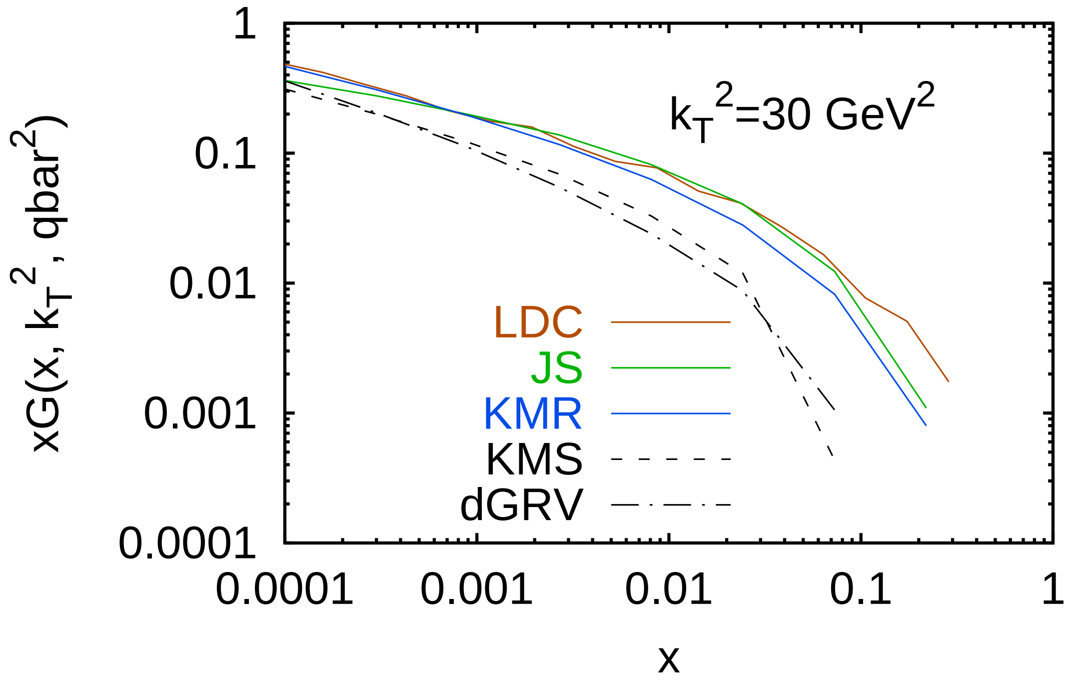
- What is the scale $\bar{q}$? Determined by the rapidity of the outgoing partons in the off-shell ME.
- What scale to use in α_s in the off-shell ME. The $q_\perp$ (or $m_\perp$) of the outgoing partons.
- How to handle situations with $k_\perp > \bar{q}$?

The unintegrated gluon can now be used to calculate various cross section with $k_\perp$-factorization, convoluting with off-shell matrix elements. We have to take care:

- What is the scale $\bar{q}$? Determined by the rapidity of the outgoing partons in the off-shell ME.

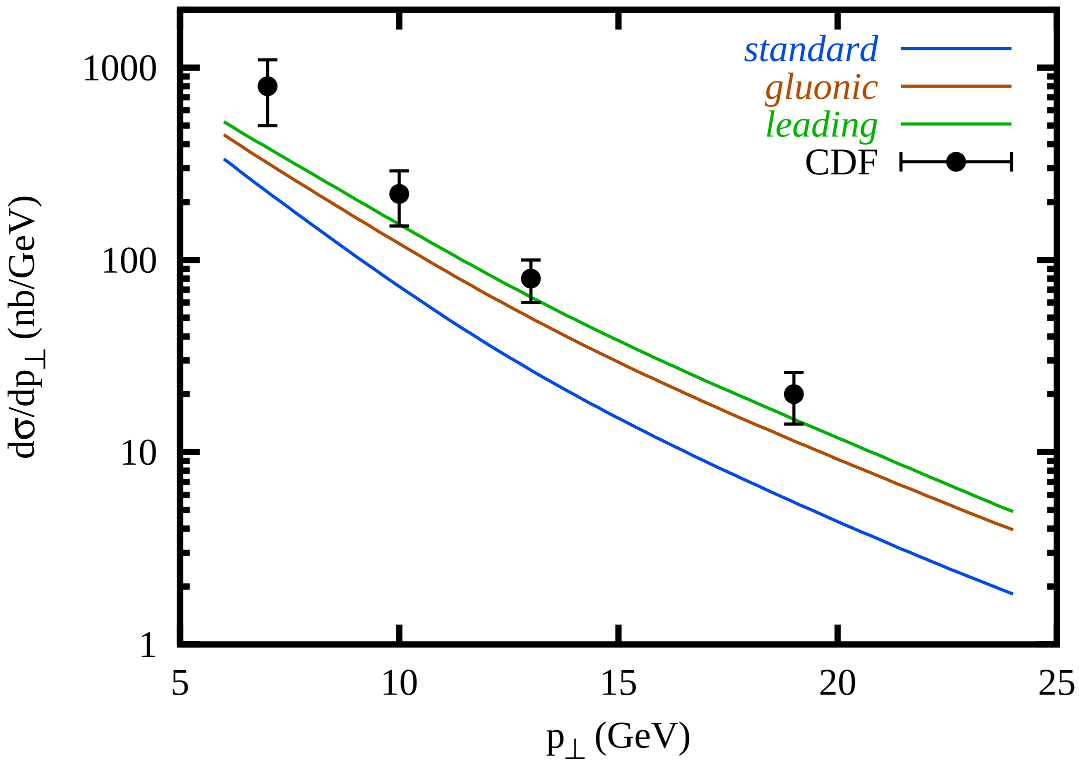
- What scale to use in α_s in the off-shell ME. The $q_\perp$ (or $m_\perp$) of the outgoing partons.

- How to handle situations with $k_\perp > \bar{q}$?
  $\mathcal{G}(x,k_\perp^2,\bar{q}^2) \approx \mathcal{G}(x,k_\perp^2)\frac{\bar{q}^2}{k_\perp^2}$

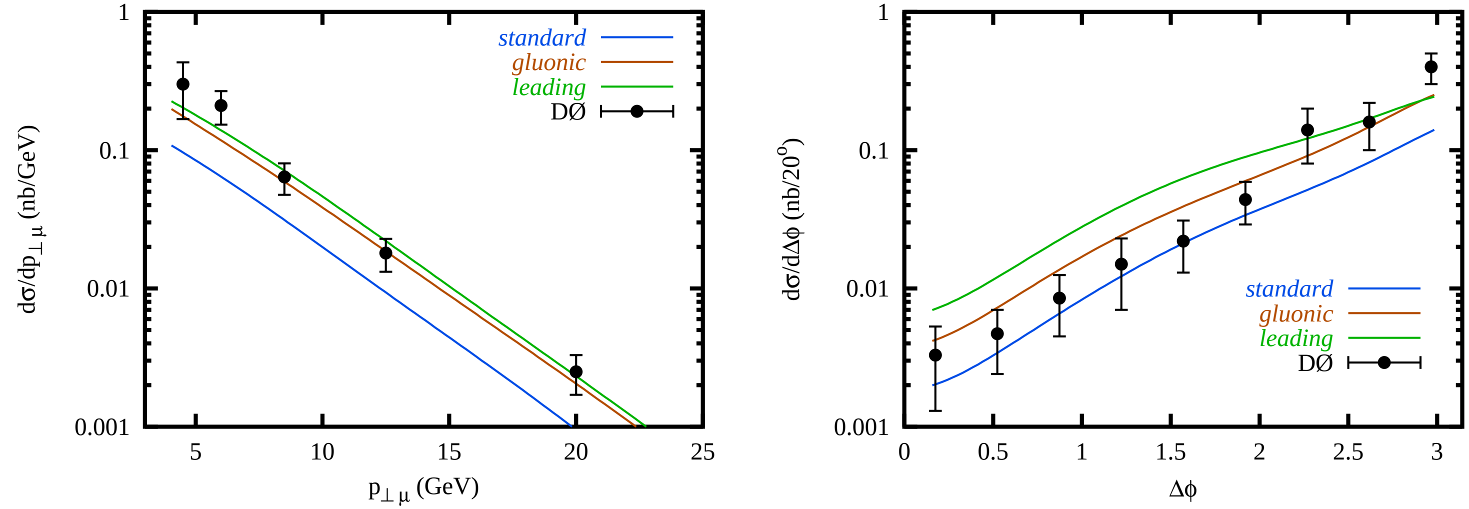


Different parameterizations differs widely, but when consistently convoluted with unintegrated ME's the difference is smaller.

Heavy quarks @ Tevatron

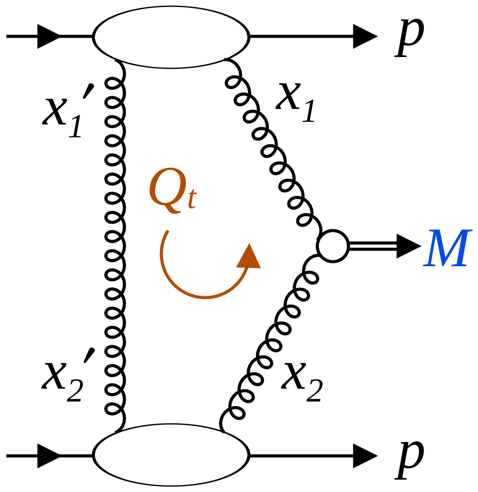


B mesons from CDF (2002)



muons from DØ

Exclusive Diffractive Higgs

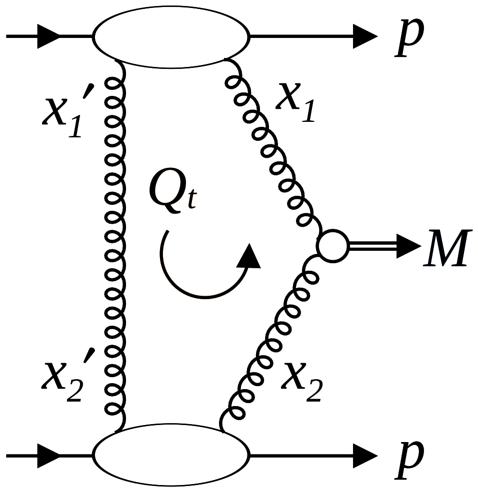


$$\frac{d\sigma_M^{\text{excl}}}{dM^2dy} = \frac{d\mathcal{L}}{dM^2dy}\hat{\sigma}_{gg\to M}(M^2)$$

$$M^2\frac{d\mathcal{L}}{dM^2dy} = S^2L$$

$$L = S^2\left(\frac{\pi}{(N_c^2-1)b}\int\frac{dQ_t^2}{Q_t^4}f_g(x_1,x_1',Q_t^2,M^2/4)f_g(x_2,x_2',Q_t^2,M^2/4)\right)^2$$

Exclusive Diffractive Higgs



$$\frac{d\sigma_M^{\text{excl}}}{dM^2dy} = \frac{d\mathcal{L}}{dM^2dy}\hat{\sigma}_{gg\to M}(M^2)$$

$$M^2\frac{d\mathcal{L}}{dM^2dy} = S^2L$$

$$L = S^2\left(\frac{\pi}{(N_c^2-1)b}\int\frac{dQ_t^2}{Q_t^4}f_g(x_1,x_1',Q_t^2,M^2/4)f_g(x_2,x_2',Q_t^2,M^2/4)\right)^2$$

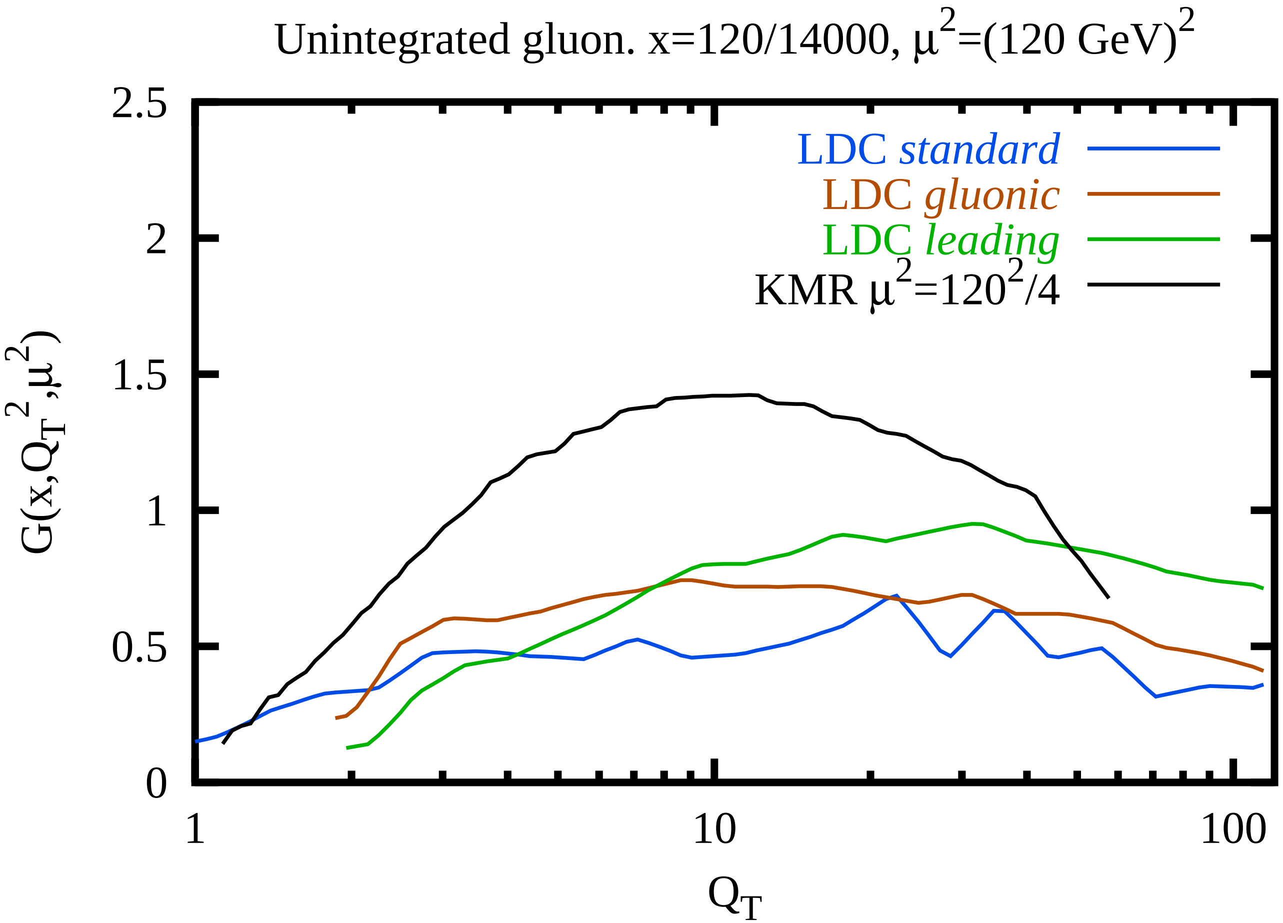
f_g is the un-integrated, off-diagonal gluon density.

S^2 is a soft survival probability.

b is the t-slope of the proton.

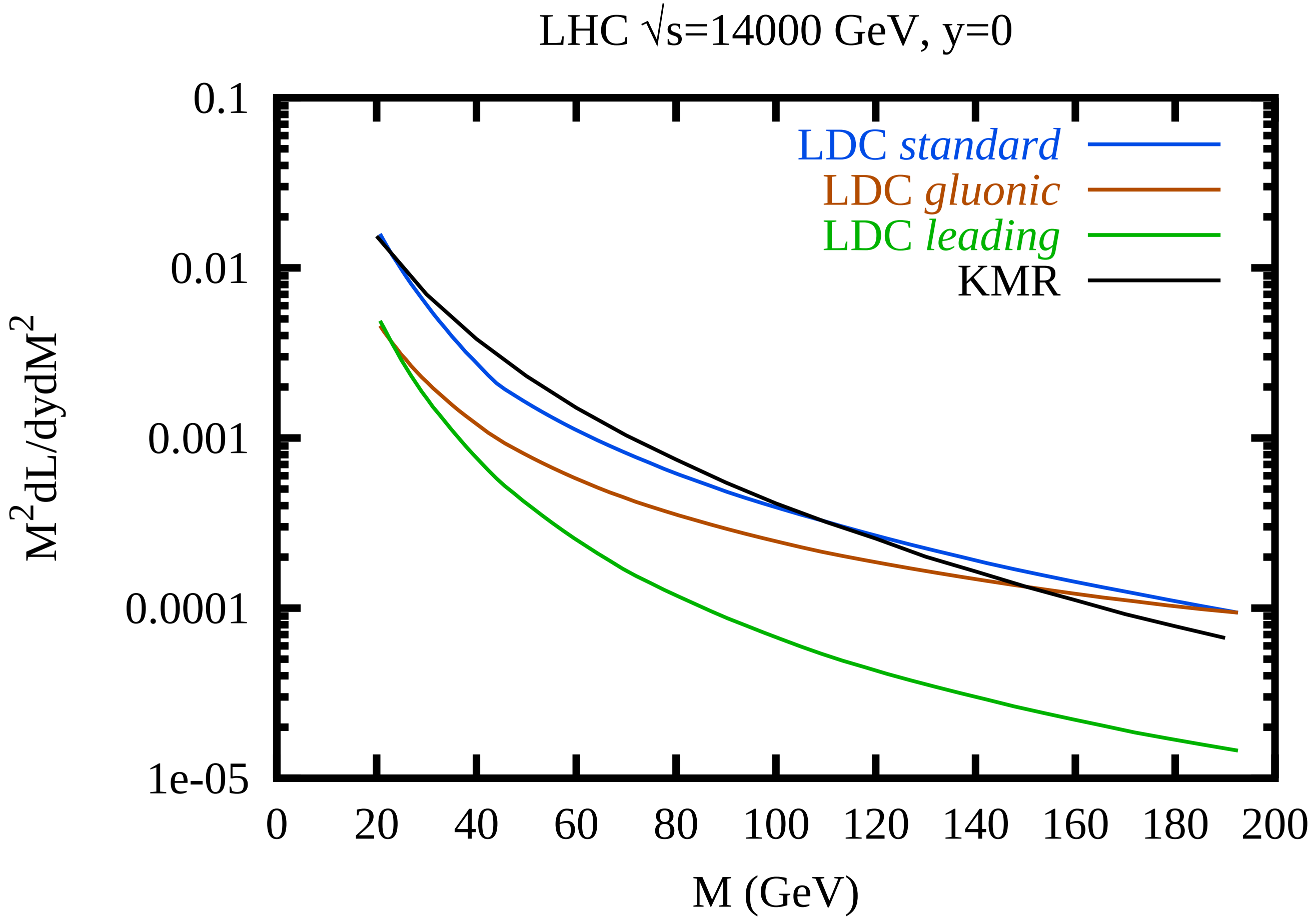
$$f_g^{\mathrm{KMR}}(x, x', Q_t^2, M^2/4) = R_g \frac{\delta}{\delta Q_t^2}\left[\sqrt{T(Q_t, M/2)} xg(x, Q_t^2)\right]$$

$$f_g^{\mathrm{LDC}}(x, x', Q_t^2, M^2) = R_g \sqrt{\Delta_S(Q_t^2, M^2)}\, \mathcal{G}(x, Q_t^2)$$



In the luminosity function the Sudakov hits you at small Q_T and the $1/Q_T^4$ at large. $\langle Q_T \rangle \approx 2-3$ GeV.

Results


LHC √s=14000 GeV, y=0
0.1
0.01
0.001
0.0001
1e-05
0 20 40 60 80 100 120 140 160 180 200
M (GeV)
$M^2 dL/dydM^2$
LDC *standard*
LDC *gluonic*
LDC *leading*
KMR

Conclusions

- $k_\perp$-factorization is maturing. NLO is coming?
- Non leading terms are very important.
- Gluon ladders with only singular terms in the splitting function works OK for final states.
- Add non-leading terms and quarks and things get more difficult, although F_2 looks fine.