Unintegrated pdfs in CCFM

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- CCFM equation
  fits to F_2
- starting scale
- choice of factorsiation scale
- initial condition
- intrinsic k_t
- small k_t region in evolution
- conclusion

CCFM equation: one loop — all loops

$$\mathcal{A}(x,k_t,\bar{q}) = \mathcal{A}_0(x,k_t)\Delta_s(\bar{q},Q_0) + \int \frac{dz}{z}\int \frac{d^2q}{\pi q^2}\Theta(\bar{q}-zq)\cdot\Delta_s(\bar{q},zq)\tilde{P}(z,q,k_t)\mathcal{A}\left(\frac{x}{z},k_t',q\right)$$

CCFM Splitting fct: $\tilde{P}(z,q,k_t) = \frac{\bar{\alpha}_s(q(1-z))}{1-z} + \frac{\bar{\alpha}_s(k_t)}{z}\Delta_{\mathrm{ns}}(z,q,k_t)$

Sudakov $\Delta_s(a,b)$: **probability for no radiation in $[a,b]$**

angular ordering: $\bar{q} > z_n q_n, q_n > z_{n-1}q_{n_1}, ..., q_1 > Q_0$

small x (all loops)

- **BFKL limit ($z \to 0$)**
- **angular ordering**

$\to$ **no restriction on q_i**

large x (one loop)

- **DGLAP limit ($z \gg 0$)**
- **DGLAP splitting fct $\tilde{P}$ with $\Delta_{\mathrm{ns}} = 1$**
- **angular ordering $\to q_i$ ordering**

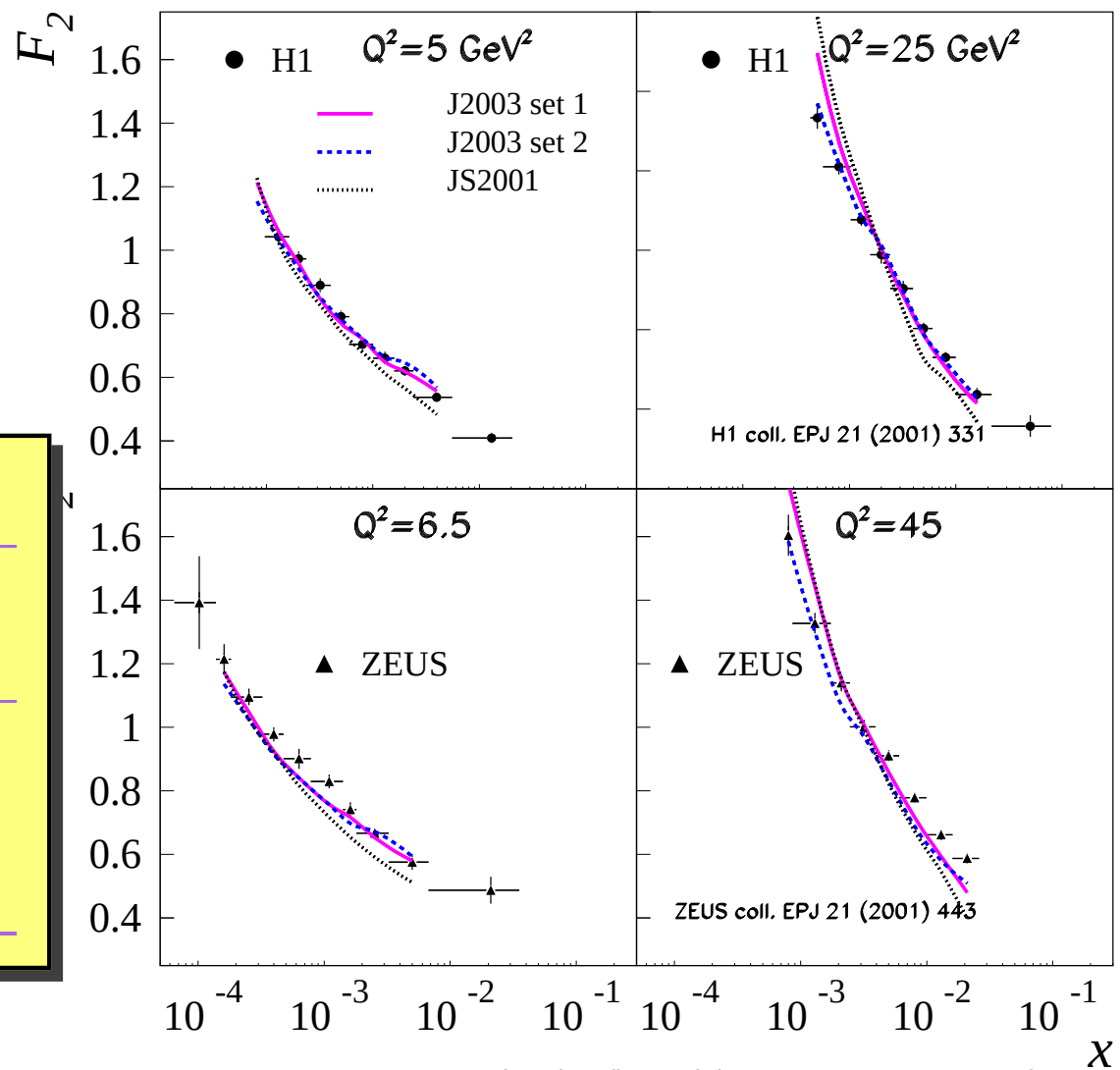
Precision fits to $F_2(x, Q^2)$

With $\sigma = \int dk_t^2 dx_g \mathcal{A}(x_g, k_t^2, \bar{q}) \sigma(\gamma^* g^* \to q\bar{q})$ fit $F_2(x, Q^2)$

- more precise data:
  H1 NPB 470 (1996) 3., EPJ 21 (2001) 331.
  ZEUS ZPC 72 (1996) 399., EPJ 21 (2001) 443.
- fit $Q^2 > 4.5$ GeV^2, $x < 0.005$
- small k_t - region ?
- full splitting function ?

Fits to $F_2(x, Q^2)$

set	k_t^{cut} (GeV)	χ^2/ndf $ndf = 248$
$k_t^{cut} = Q_0$	**1.33**	**1.29**
full splitting	**1.18**	**1.18**
JS2001	**0.25**	**4.8**

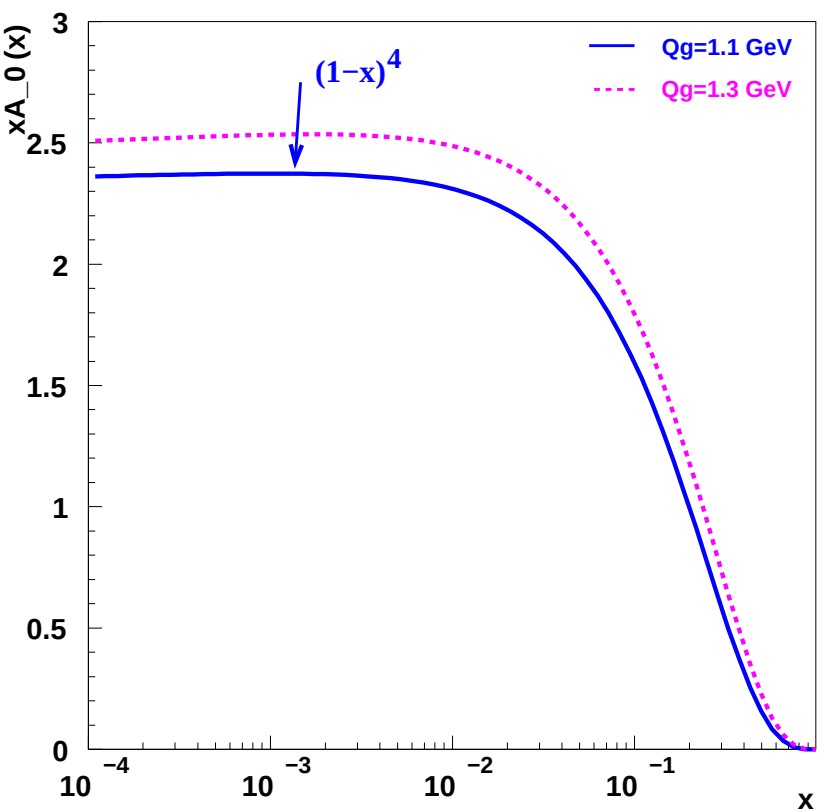


All loop fits to $F_2(x, Q^2)$

- all-loop splitting function
- full angular ordering
- use off-shell BGF ME,only gluons
- $m_q = 0.250$ GeV, $m_c = 1.5$ GeV
- fit F_2 for $Q^2 > 4.5$ GeV^2, $x < 0.005$
- similar χ^2 for different intrinsic k_t

  Gaussian: 0.3 - 0.9 GeV
- sensitivity on starting scale

initial gluon density



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- sensitivity on starting scale
- find 2 solutions (at least)...
- large x not really constrained
- small x similar

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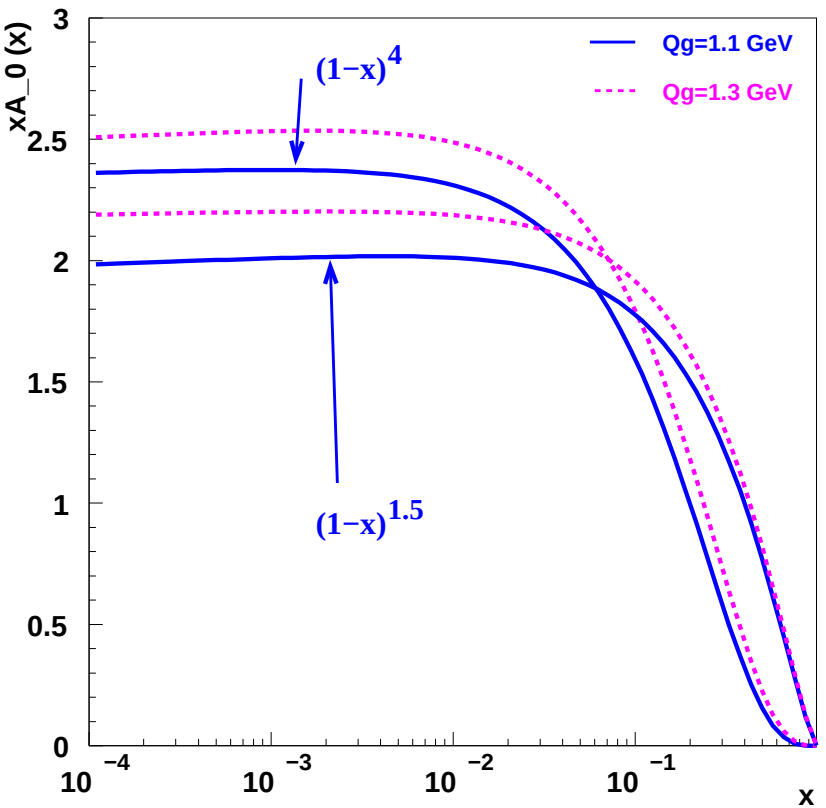

All loop fits to $F_2(x, Q^2)$ choice of factorization scale ...

- **CCFM: ordering in rapidity of emitted gluons**
- $z_{i-1} q_{i-1} < q_i < \bar{q}$ **with** $q_i = x_{i-1}\sqrt{s\xi_i} = \frac{p_{ti}}{1-z_i}$
- **what is factorization scale** $\bar{q}$**?**
- $\bar{q}^2 = x_g^{(2)} \Xi s = \hat{s} + Q_t^2$
- **or related to** p_t **of quarks ?** $\frac{p_{ti}}{1-z_i} \ll \hat{s}$
- **fit** F_2 **for** $Q^2 > 4.5$ **GeV**^{2}**,** $x < 0.005$

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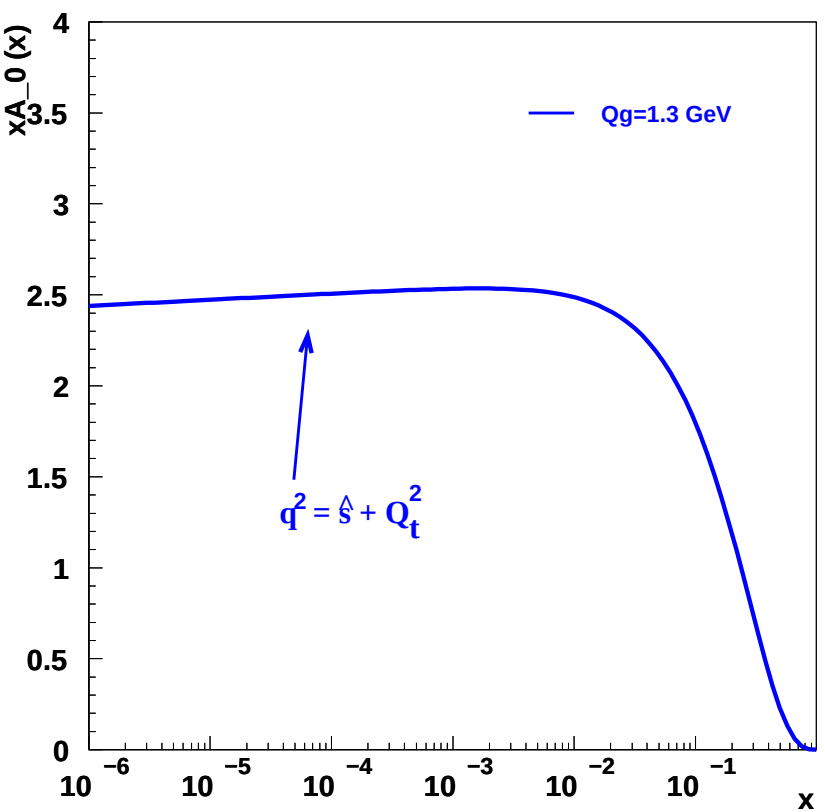

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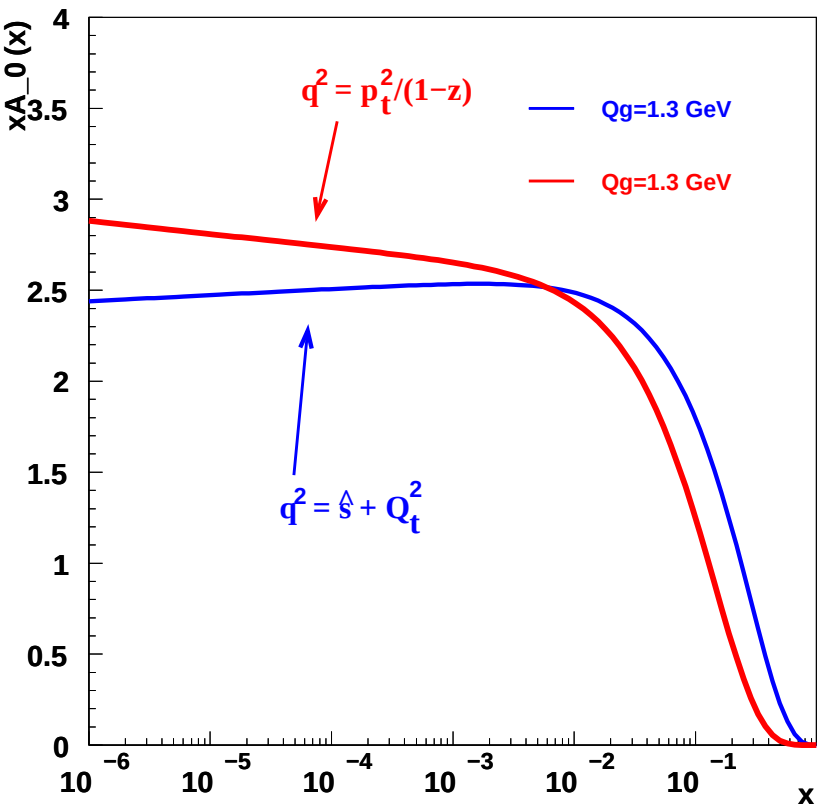
- **change of small** x **behavior...**
- **shorter evolution ladder**

initial gluon density



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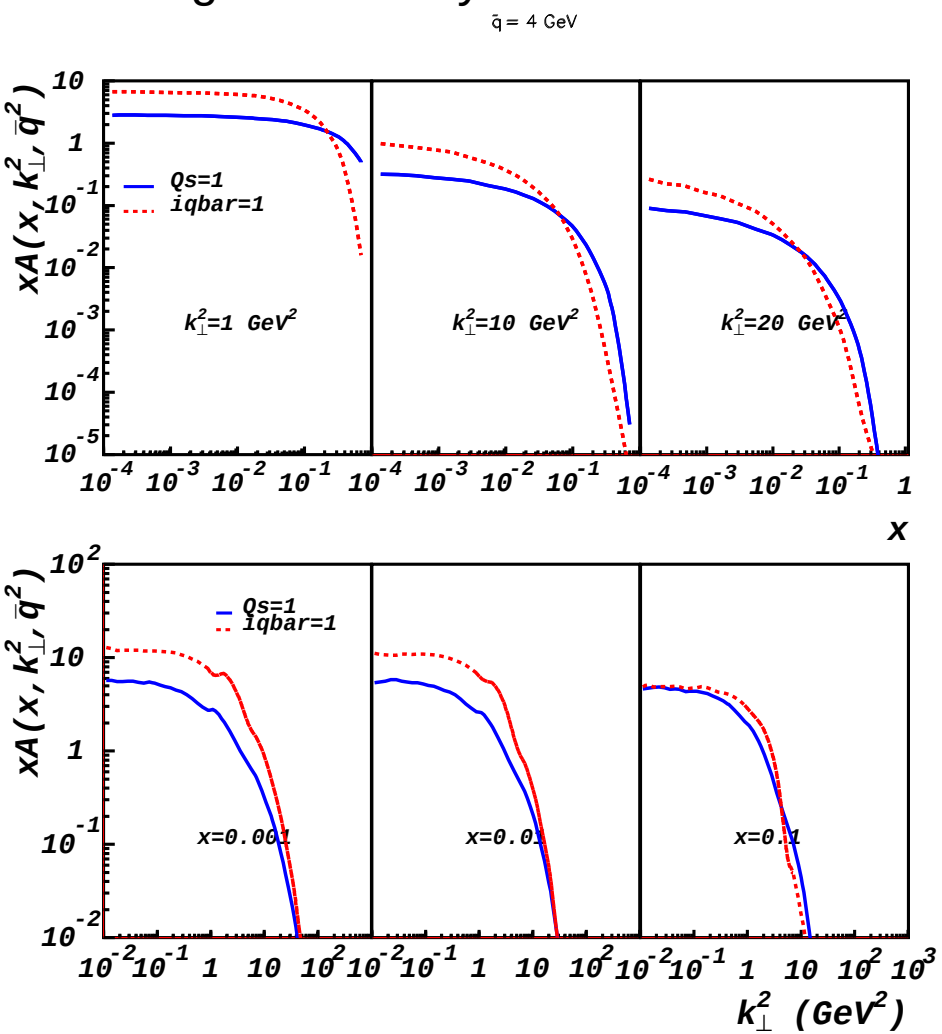
- **fit** F_2 **for** $Q^2 > 4.5$ **GeV**^{2}**,** $x < 0.005$
- **change of small** x **behavior...**
- **shorter evolution ladder**
- **different shape in** k_t

initial gluon density



Effect of initial condition — small k_t - region

$$\mathcal{A}(x, k_t, \bar{q}) = \mathcal{A}_0(x, k_t)\Delta_s(\bar{q}, Q_0) + \int \frac{dz}{z} \int \frac{d^2q}{\pi q^2} \Theta(\bar{q} - zq)\Delta_s(\bar{q}, zq) \cdot \tilde{P}(z, q, k_t)\mathcal{A}\left(\frac{x}{z}, k_t', q\right)$$

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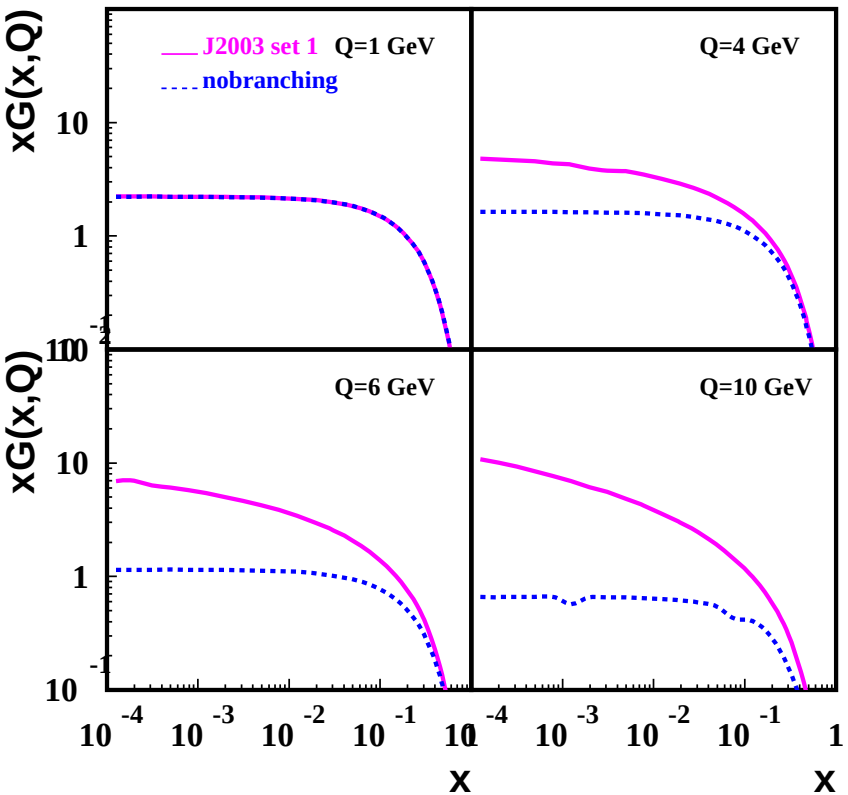
integrated pdf:
effect of evolution and initial condition
not clearly separated ...

where is:
- **small k_t region ?**
- **saturation region ?**



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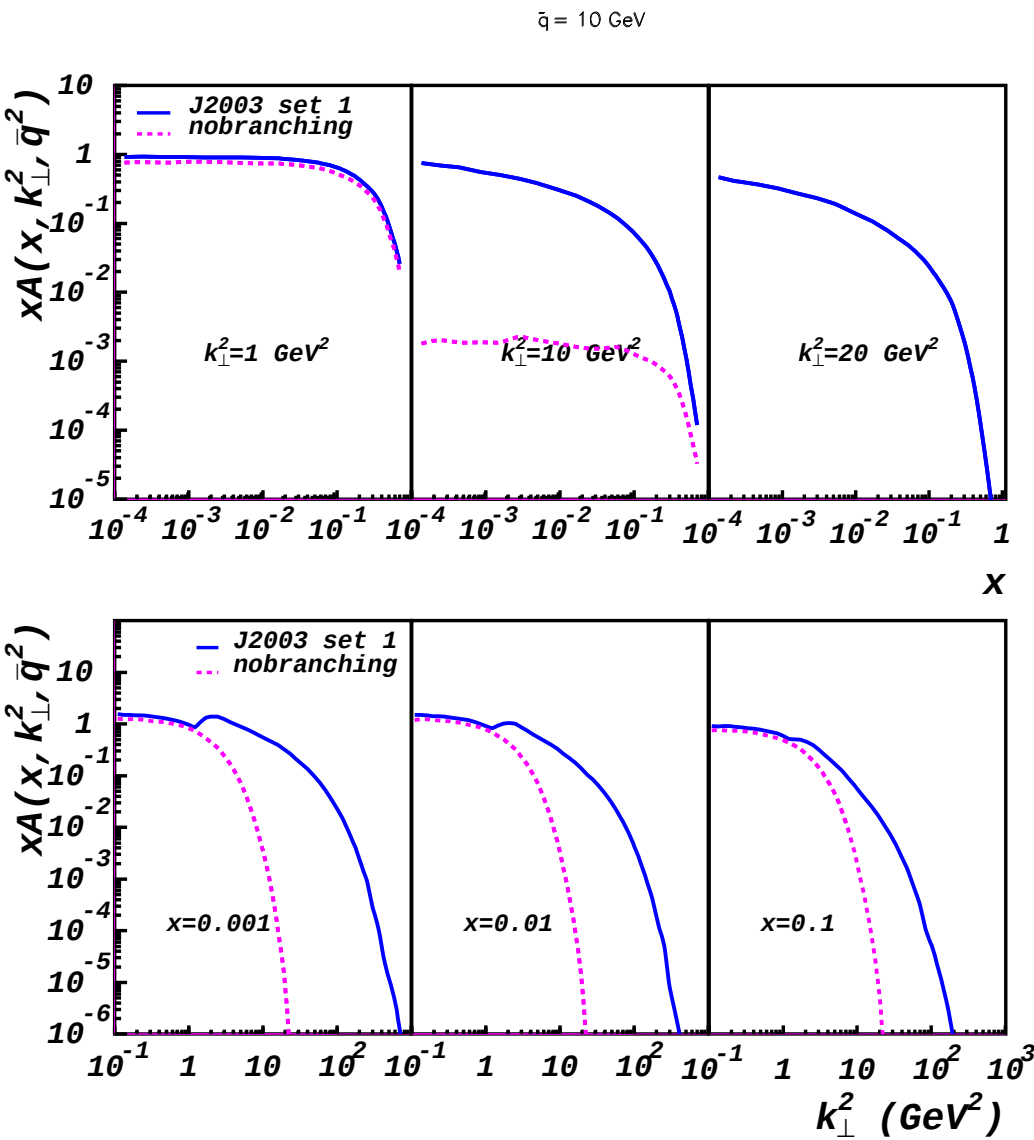
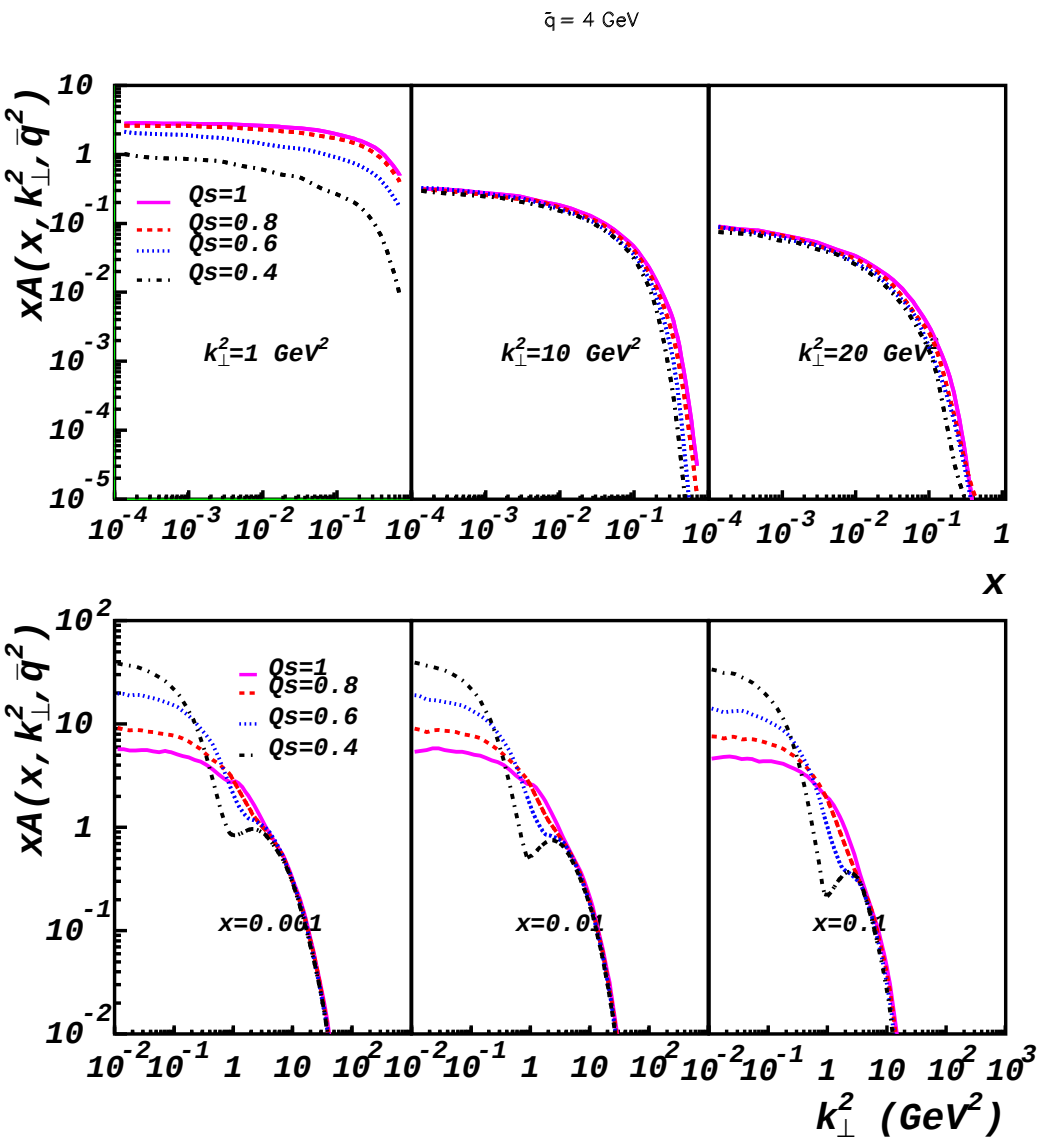
Advantage of uPDF:
initial condition clearly seen
in small k_t region
even at large scales $\bar{q}$



Effect of intrinsic k_t - small k_t - region

- $\mathcal{A}_0(x, k_t) = N x^a (1-x)^b \cdot \exp\left(-k_t^2/{Q_s}^2\right)$
- different choices for Q_s
- matching with evolution
- all describe F_2 with similar $\chi^2 \sim 1$
- large k_t tail of intrinsic k_t
- ☛ to be truncated ?

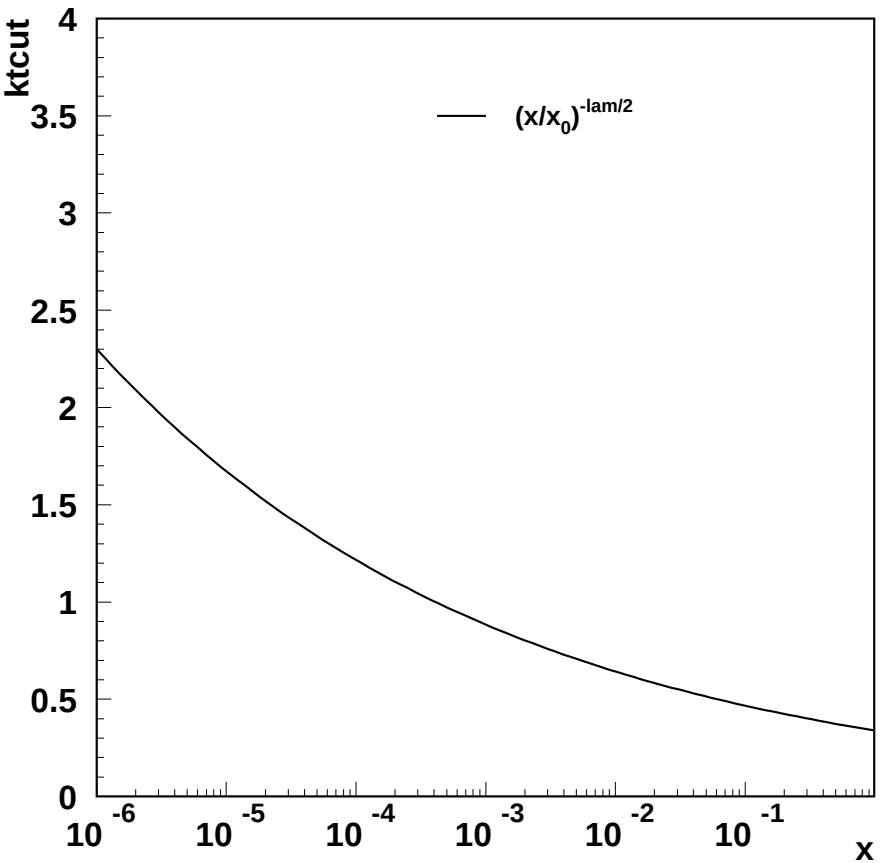


Small k_t - region - saturation

- during evolution k_t can become small
- k_t cut - freeze α_s
- k_t cut - acc. saturation model:

$$k_{t\ cut} = \left(\frac{x}{x_0}\right)^{-\frac{\lambda}{2}}$$

$x_0 = 0.004$ and $\lambda = 0.28$



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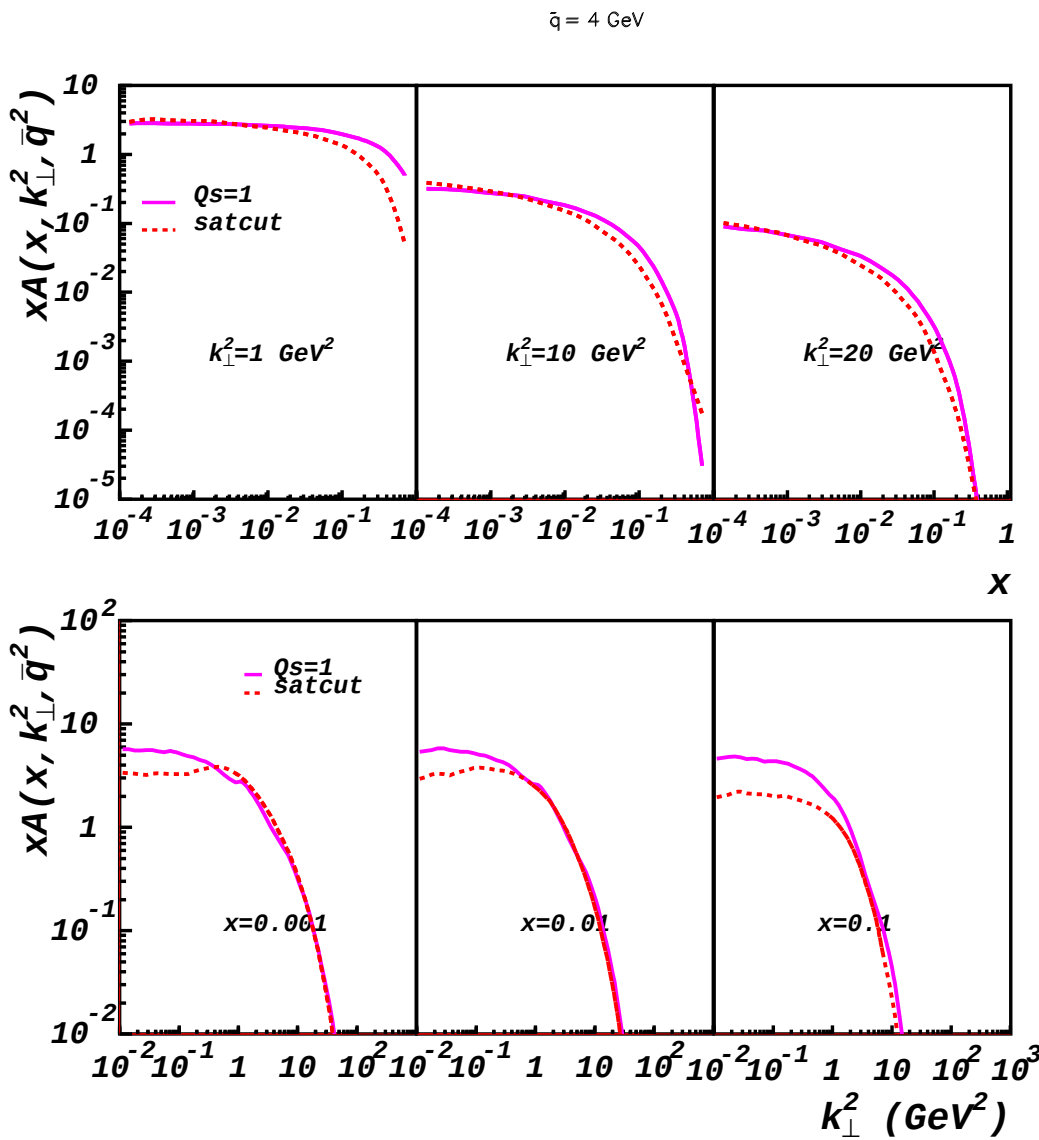

Conclusions

- **CCFM uPDFs for systematic studies**
  - ☛ **small x behavior of starting distribution**
  - ☛ **choice of factorization scale ☛ small x behavior**
  - ☛ **intrinsic k_t effects...**
  - ☛ **small k_t in evolution**
  - ☛ **saturation ?**
- **perform global fits for uPDF (including quarks)**
- **systematic studies of uPDF needed for**
  - ☛ **applications also for LHC: Higgs**