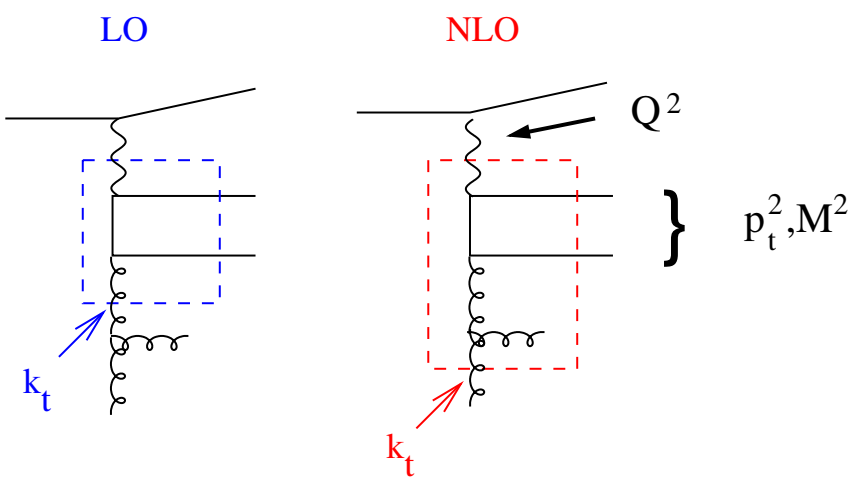
Un-integrated PDFs, Scales and Uncertainties

H. Jung, DESY

- k_t - effects - is our picture correct ?
  DGLAP vrs CCFM
- u-PDFs: uncertainties
  Scales, cutoffs etc
  further uncertainties
- conclusion

Is our picture correct ?



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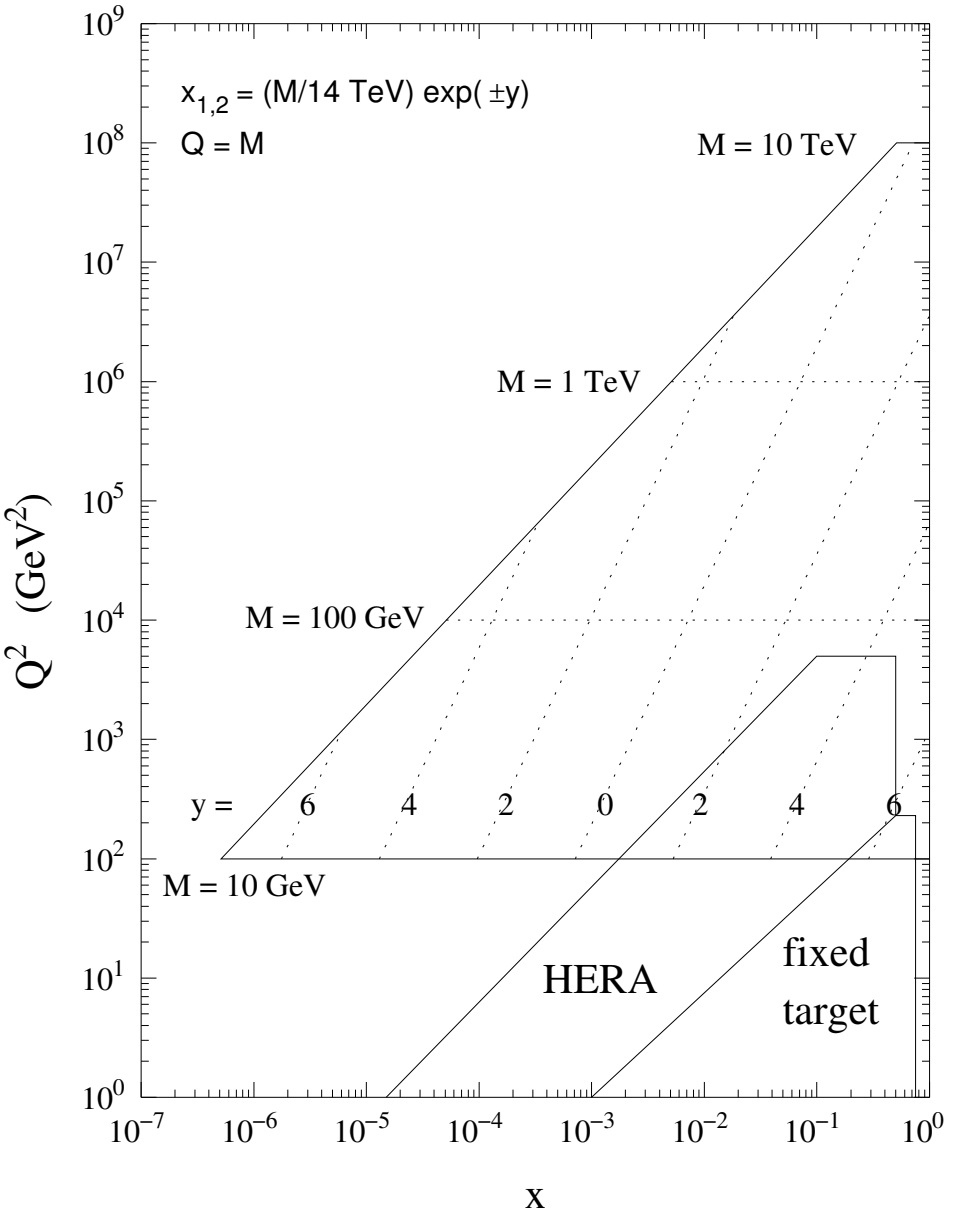

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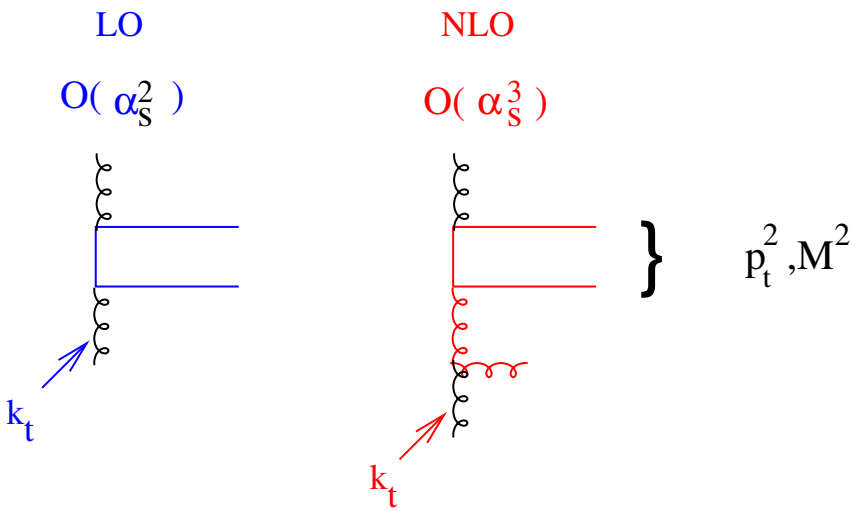

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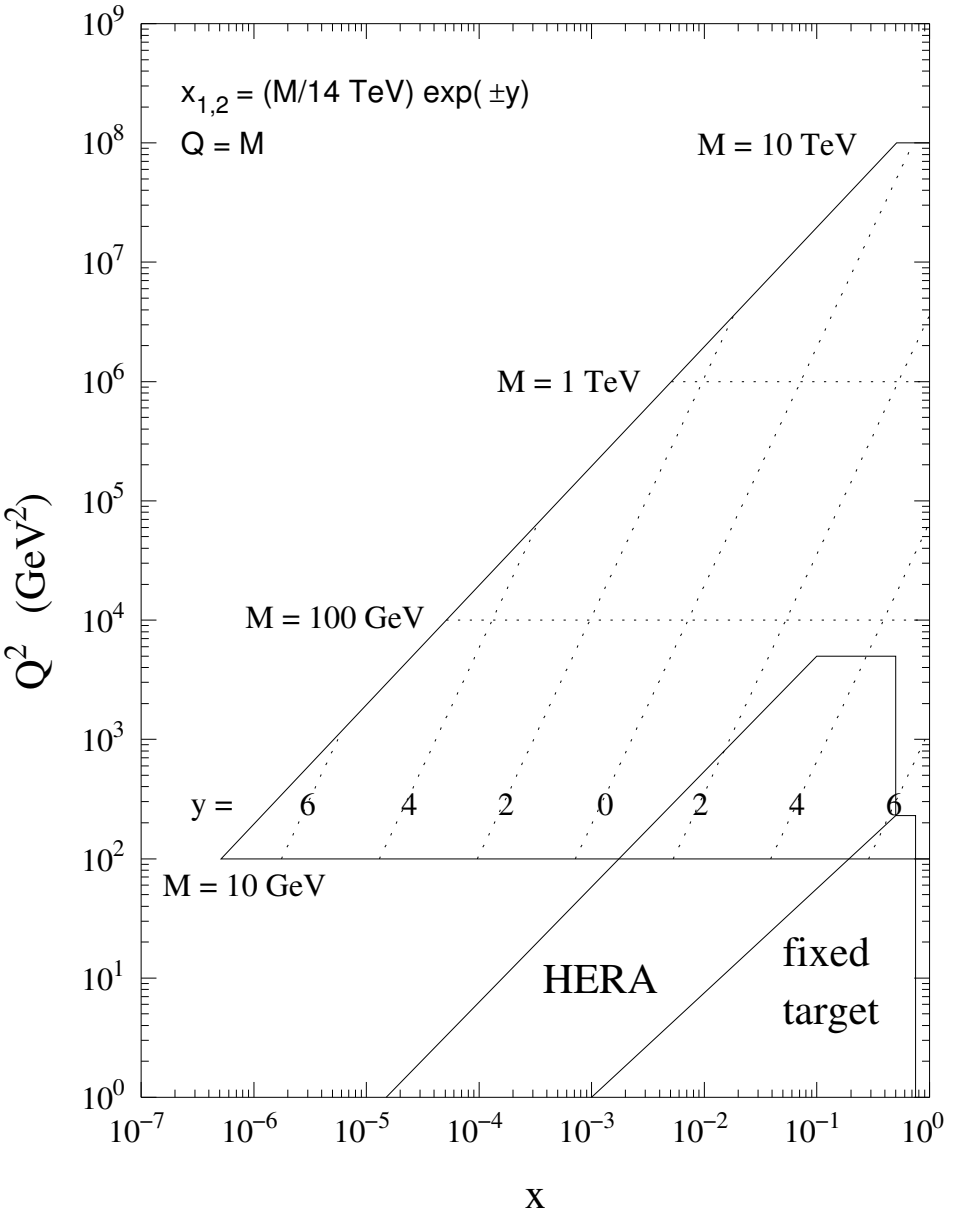

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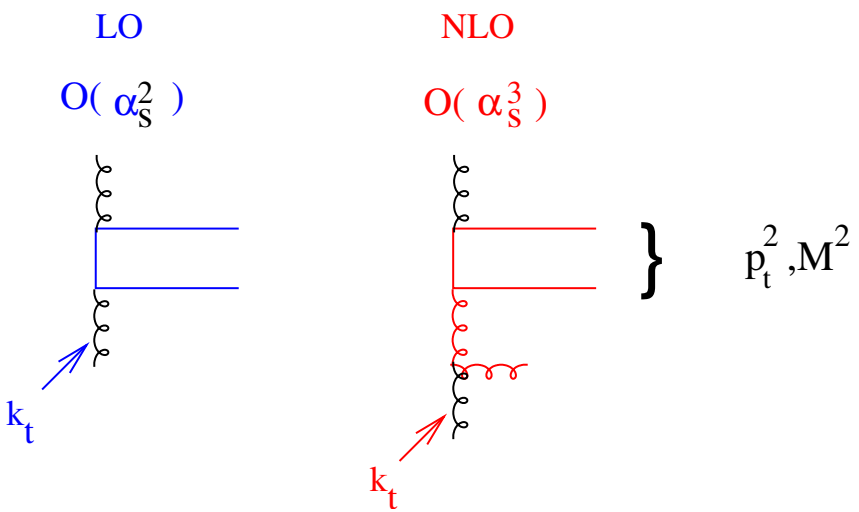

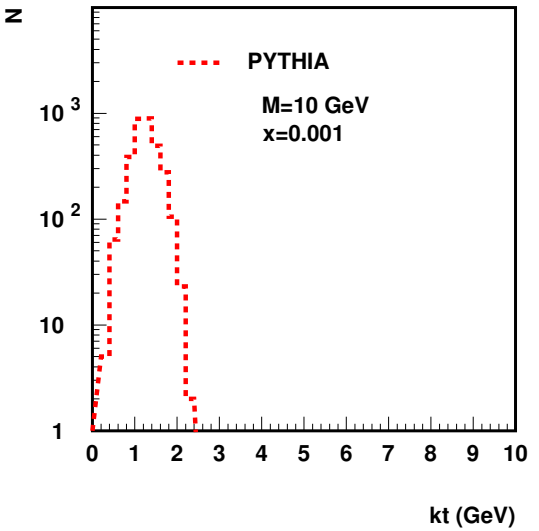

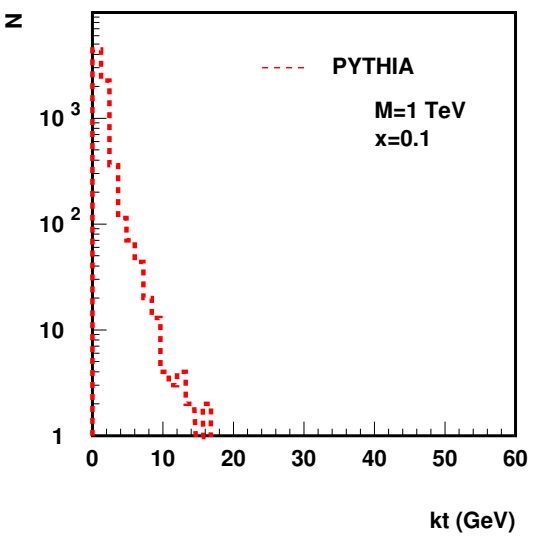

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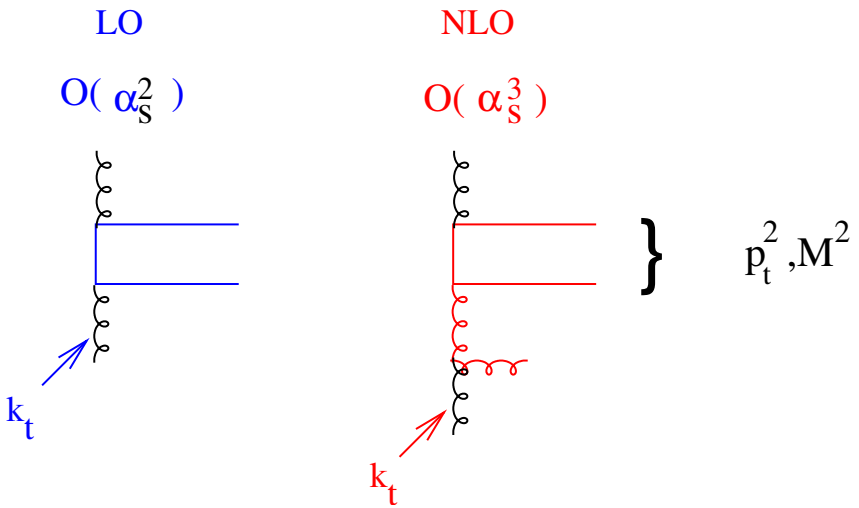

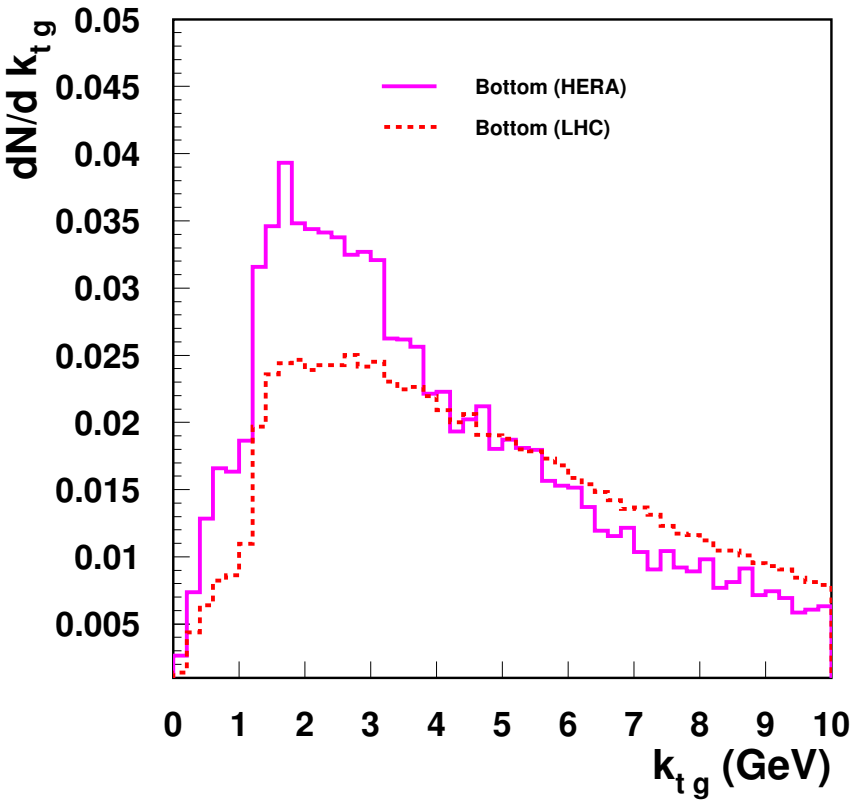

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k_t's similar for HERA and LHC !!!!

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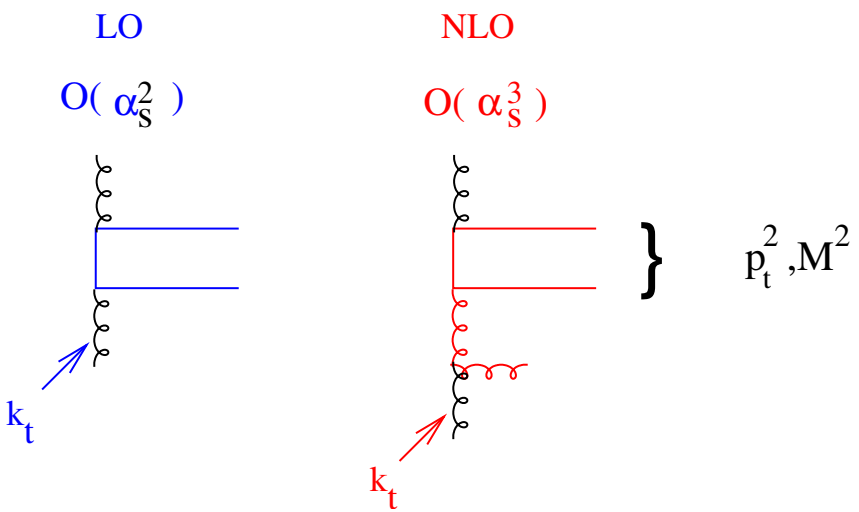

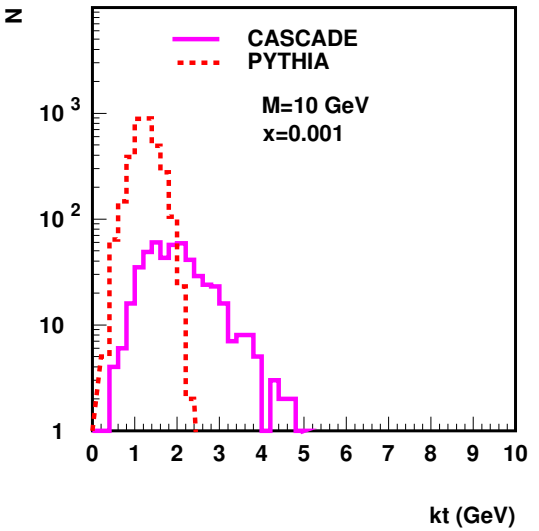

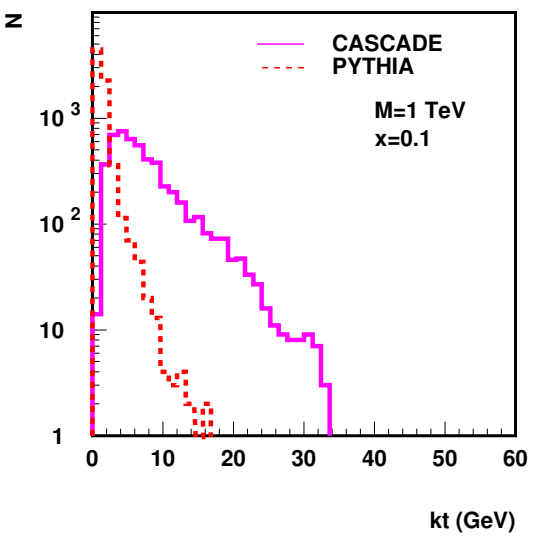

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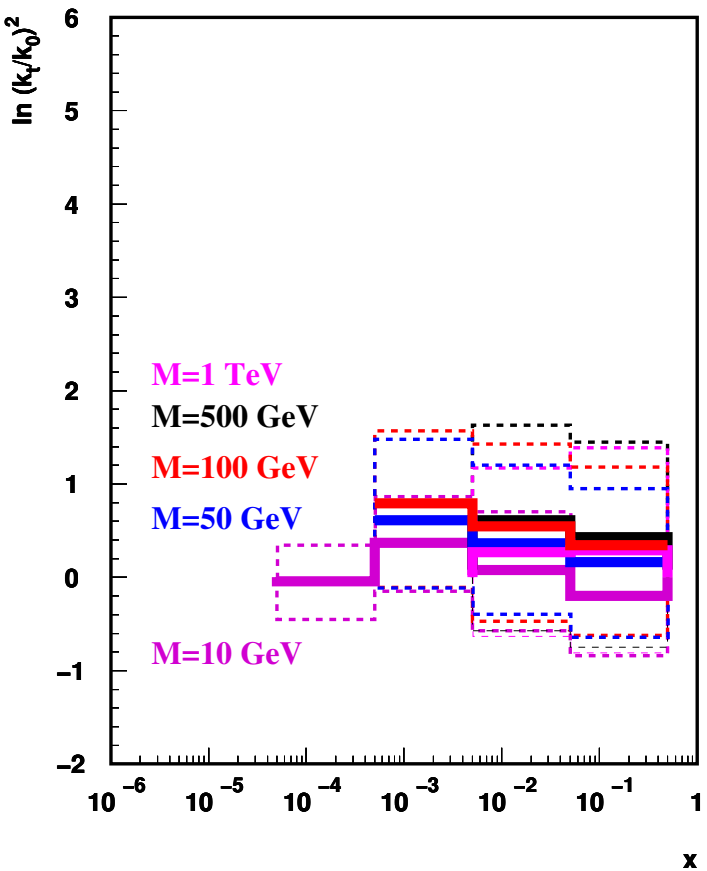
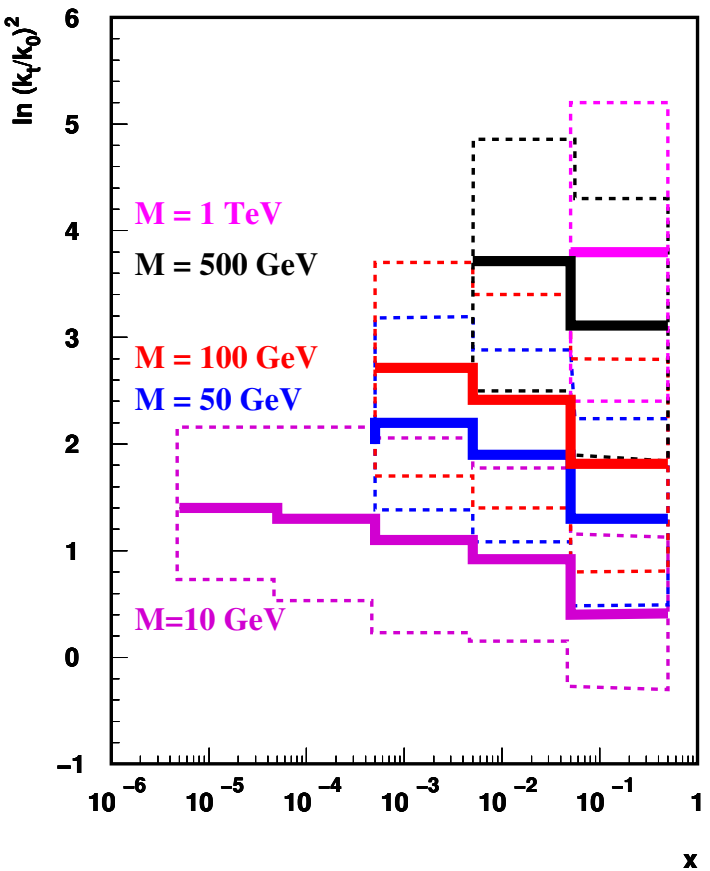
dependence on x, M^2 and scheme (DGLAP/BFKL/CCFM)???

Dependence of $< k_t >$: DGLAP vrs CCFM

DGLAP (PYTHIA)



CCFM (CASCADE)



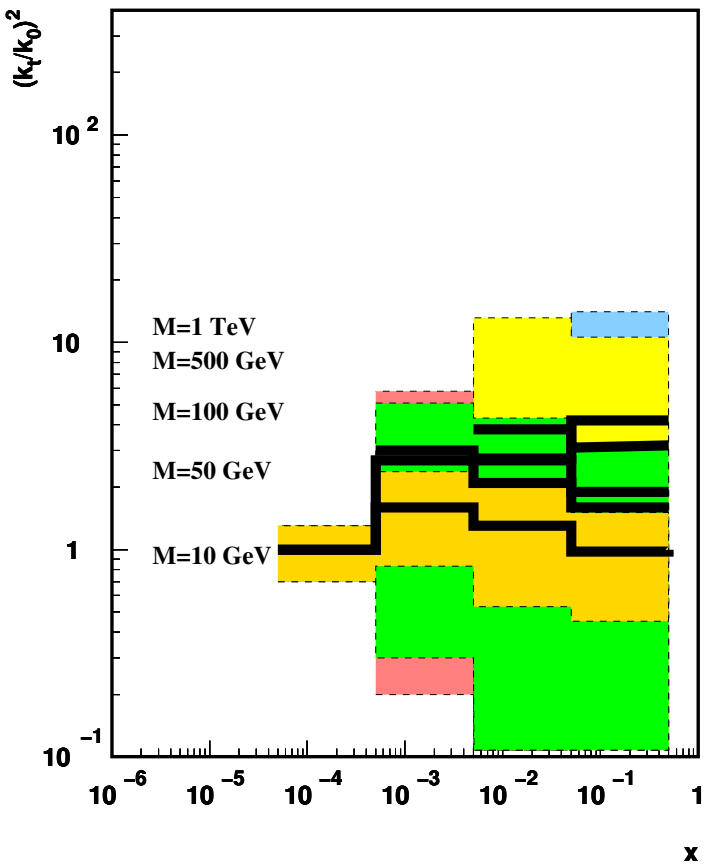
DGLAP has similar $< k_t >$'s for different x and M^2 !!!!

☛ importance of starting distribution ... saturation at low scales

BUT CCFM/BFKL (small x): increasing $< k_t >$ for decreasing x

$< k_t >$ effects: DGLAP vrs CCFM

DGLAP (PYTHIA)



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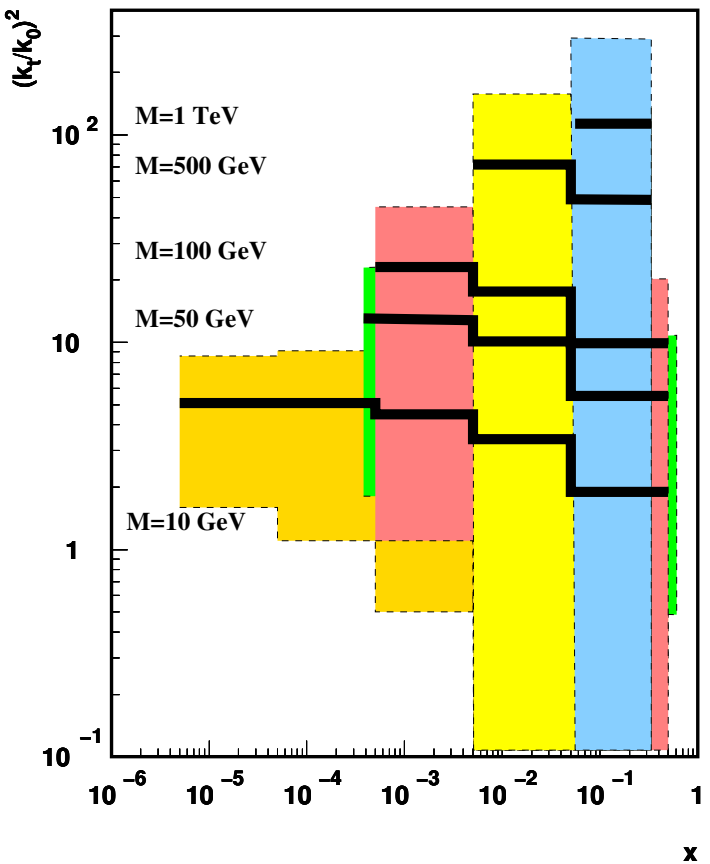

- HERA for $M < 300$ GeV
- most k_t effects can be studied at HERA
- what matters is: un-integrated parton distributions

uPDFs: uncertainties in gluon distribution

- uncertainties in uPDF
  - effect of starting distributions in x and k_t
  - effect of scale variations, renormalization - factorization scales
  - treatment of cut-offs: soft region
  - saturation effects (see talk by K. Kutak)
- choice of evolution scheme (CCFM, BFKL, etc)
  - Ordering
  - Splitting functions: treatment of DGLAP part (non-sing. terms)
  - Splitting functions: quarks (problem of double counting)
  - kinematic/consistency constraints
- benchmarks for uPDFs
  - describe at least inclusive x-section: $F_2(x, Q^2)$ and $F_2^c(x, Q^2)$
  - apply to hadronic final state calculation:
  - forward jets at HERA and/or b-production at Tevatron ?

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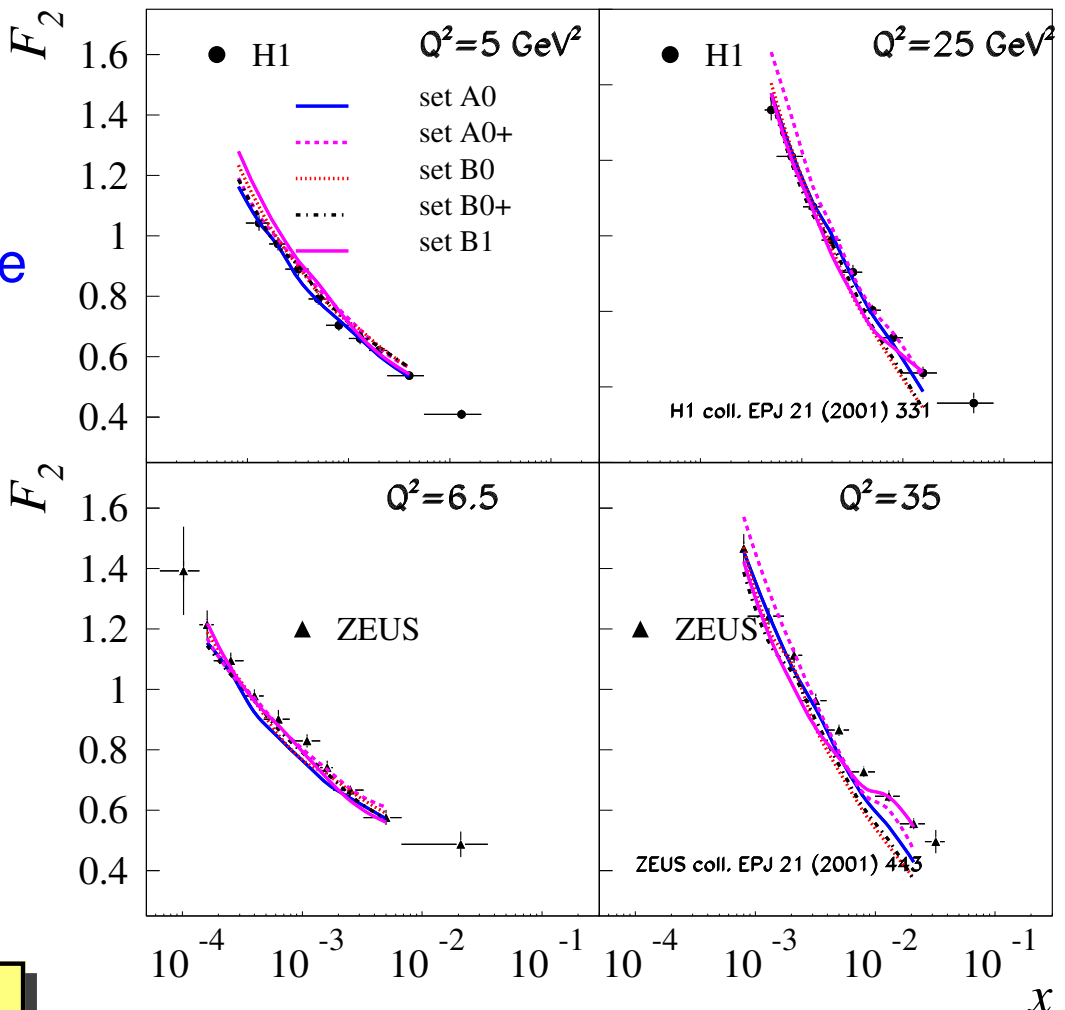
New fits to $F_2(x, Q^2)$

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 $F_2(x, Q^2)$

- available 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, $x < 0.005$
- starting scale & cut-off for resolvable branching $Q_0 = 1.3$ GeV
- quark masses: $m_q = 0.250$ GeV, $m_c = 1.5$ GeV
- initial gluon $x\mathcal{A}_0(x, k_{t0}^2)$
- investigate:
  - ☛ small k_t region during evolution
  - ☛ change of renormalization scale
  - ☛ change of factorization scale: from $q\bar{q}$ pair to q or $\bar{q}$

uPDF obtained from fit to F_2 !!!

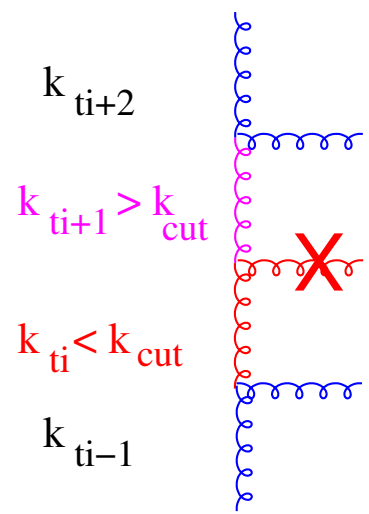


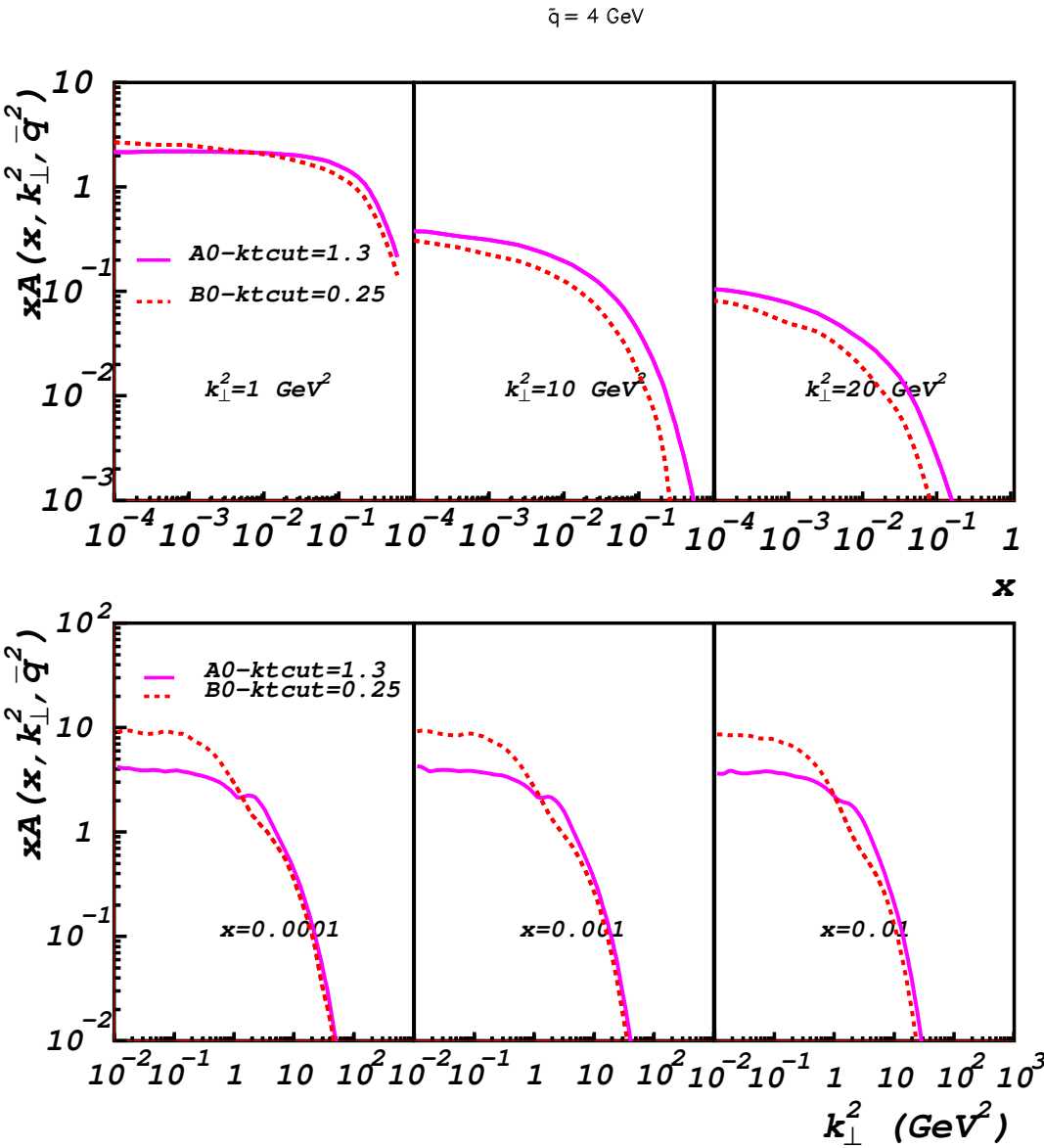
Choice of starting scales and cutoffs

- use F_2 data from H1 & ZEUS
- fit Q_0 and normalization

Treatment of soft region
w/o k_t ordering
☛ diffusion into soft

- apply $k_{t\ cut}$ resolv. branching only for $k_{\perp i} > k_{t\ cut}$
- cut for Δ_{ns}, α_s etc.
- saturate ....!





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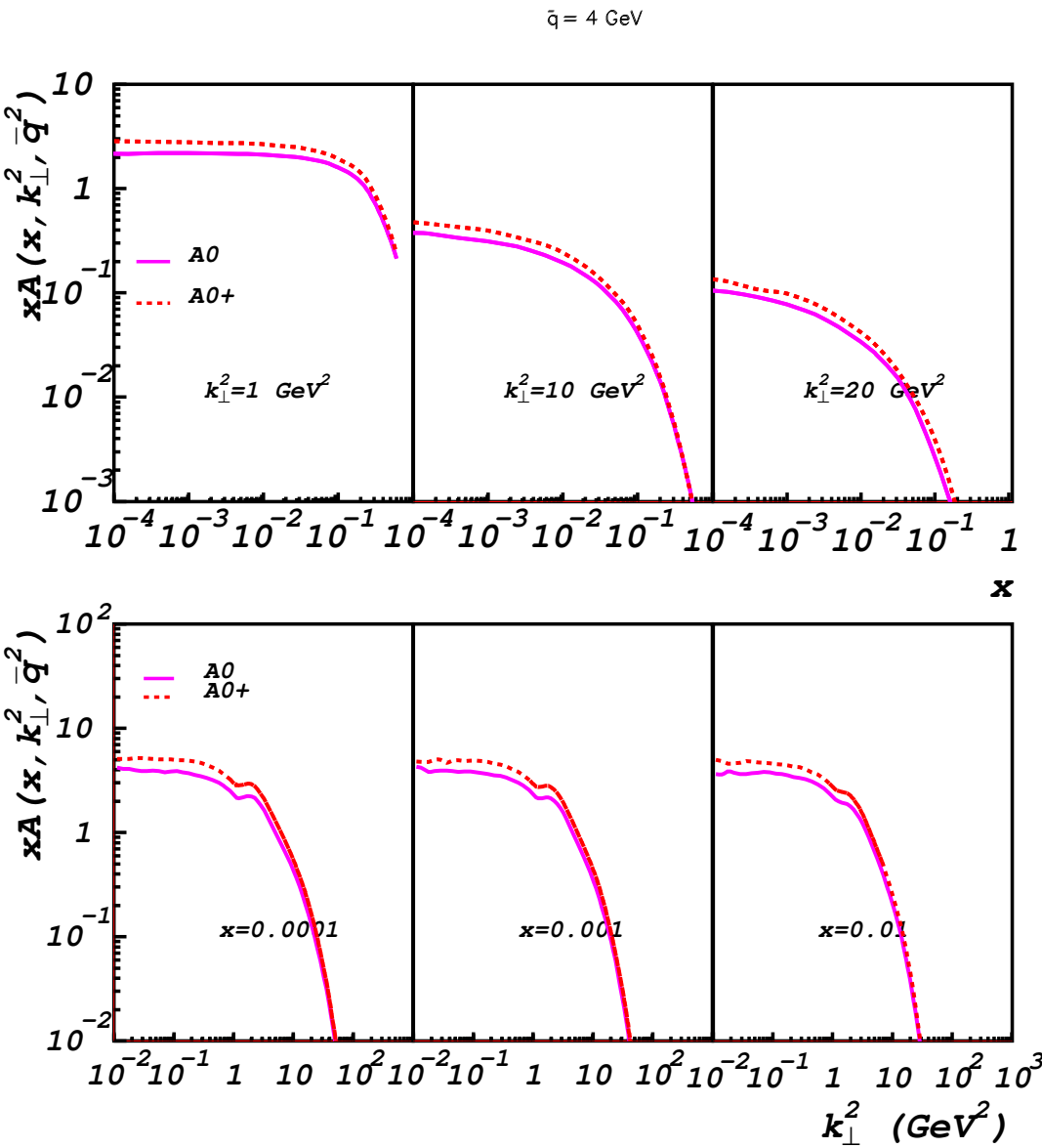
to investigate scale dep:
☛ change renorm scale
$0.25p_t^2 < \mu_r < 4p_t^2$
since no NLO for k_t-fact.
perform new fits to F_2
set A+ (set B+) ☛ $4p_t^2$



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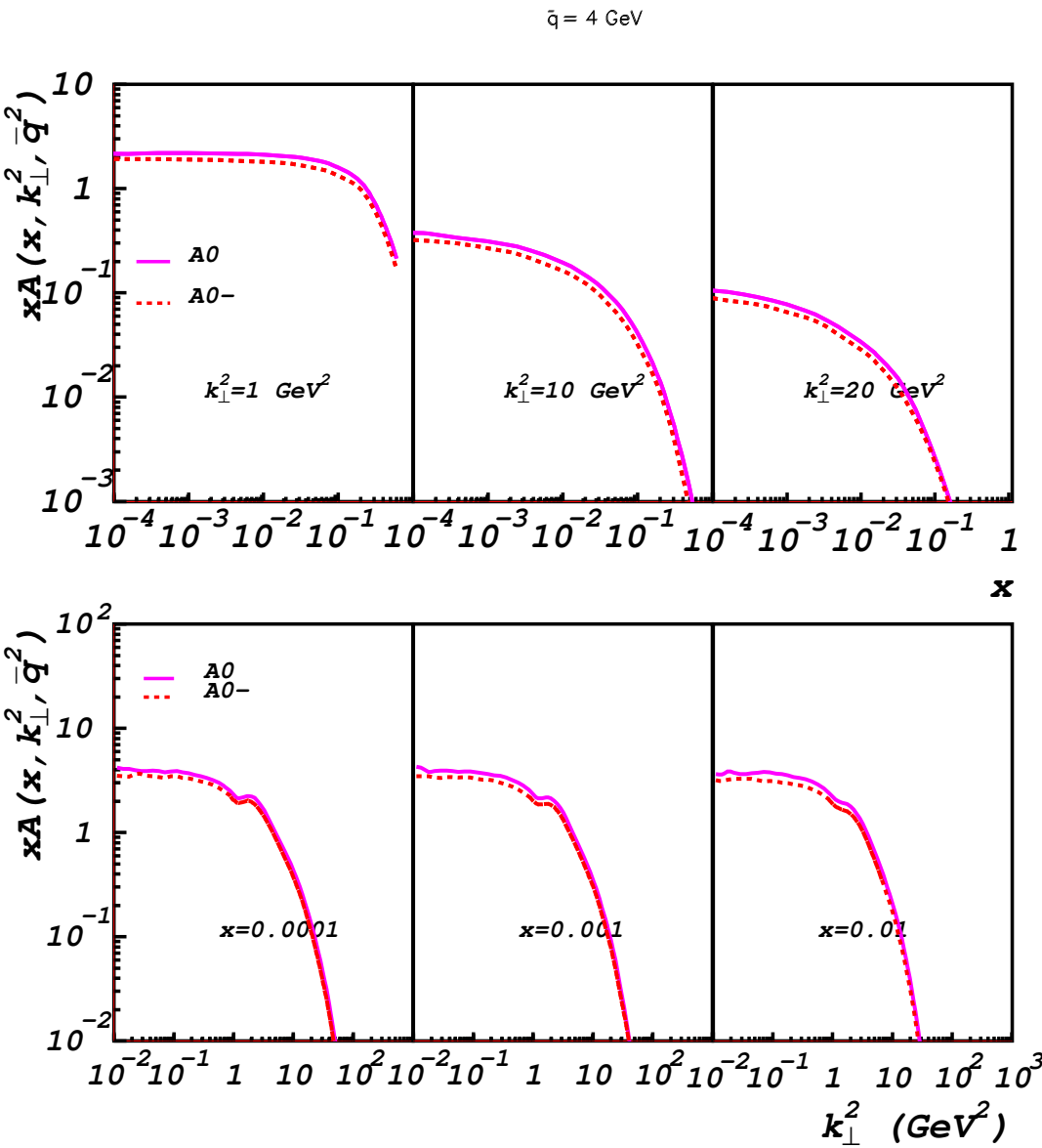

Choice of Factorization Scale $\bar{q}$

- **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** $\bar{q}$**?**
- $\bar{q}^2 = x_g \Xi s = \hat{s} + Q_t^2$
- **or related to** p_t **of quarks ?**
  $\frac{p_{ti}}{1-z_i} \ll \hat{s}$
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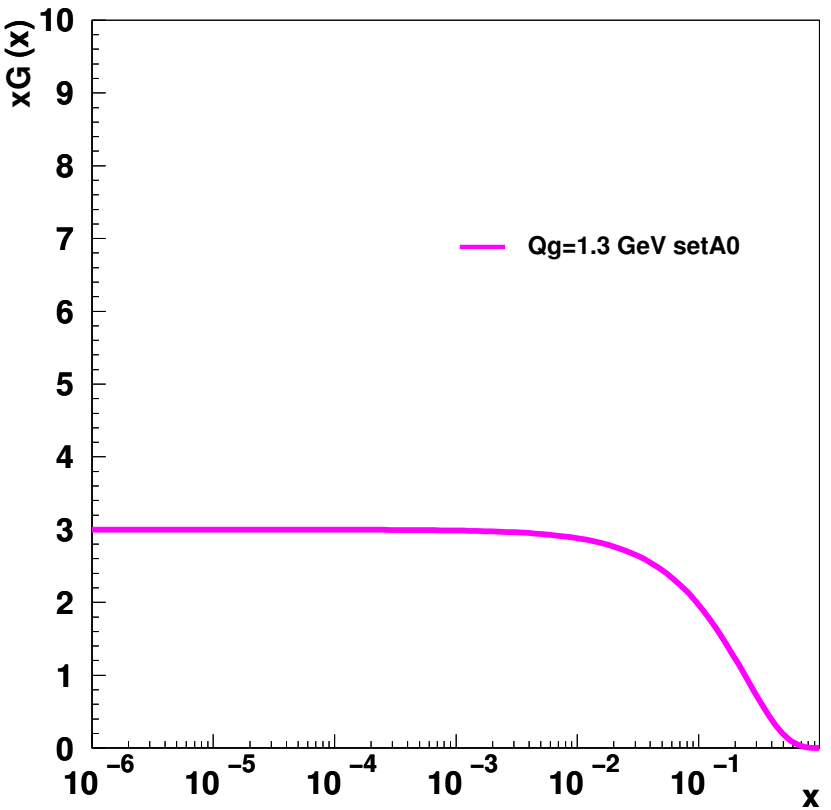

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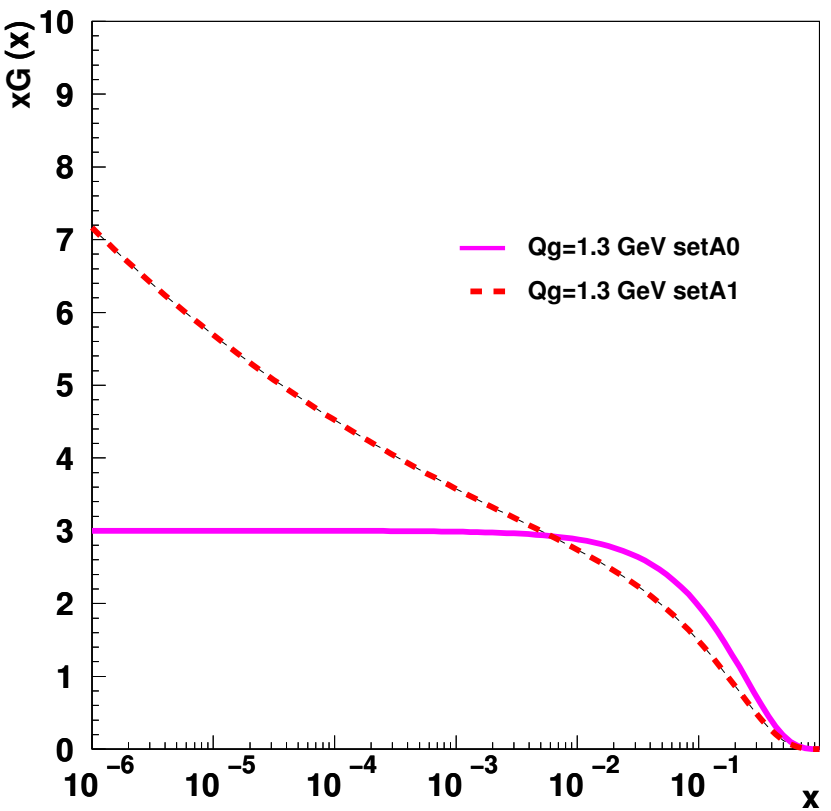
- **change of small** x **behavior...**
- **shorter evolution ladder**



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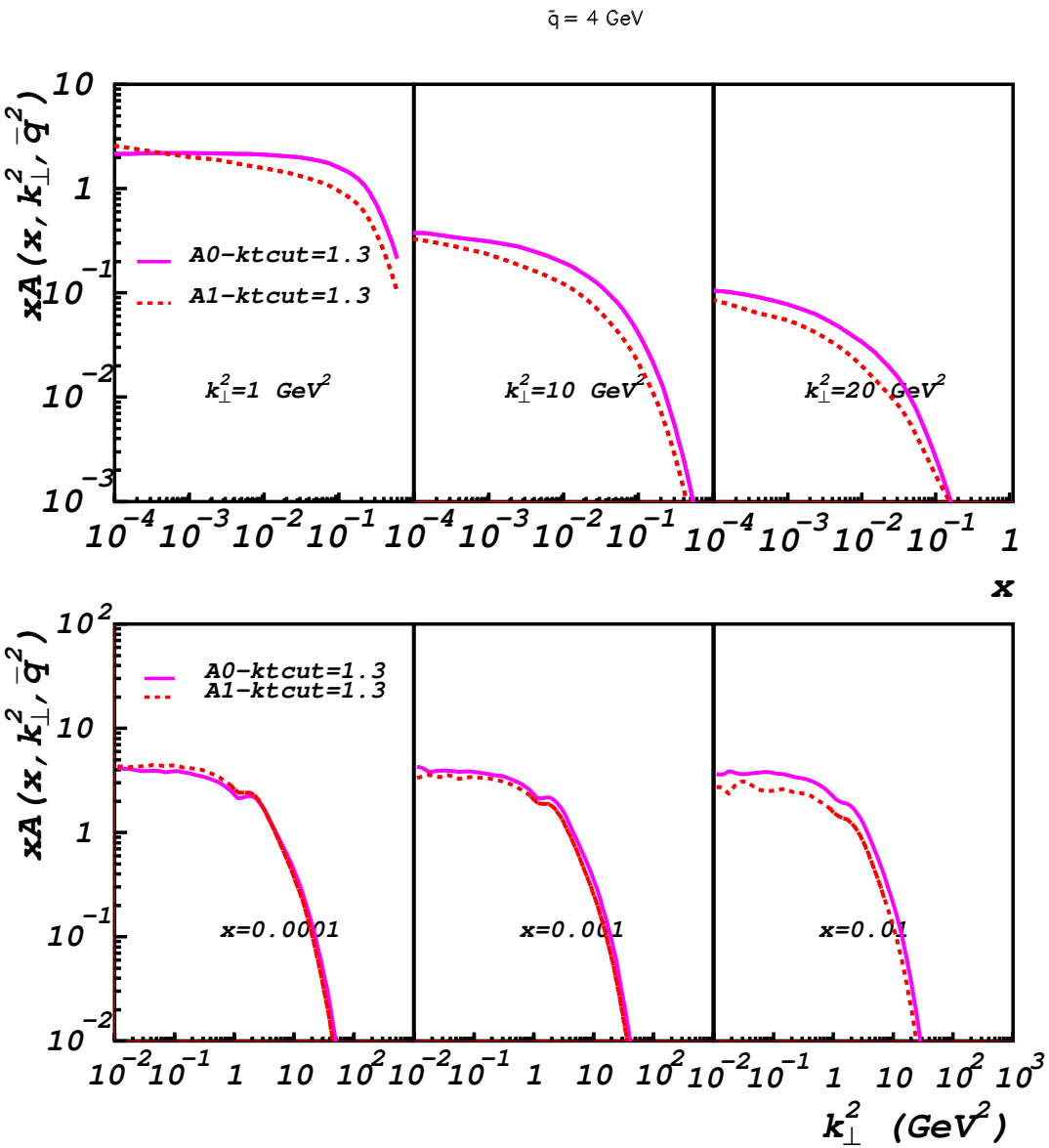
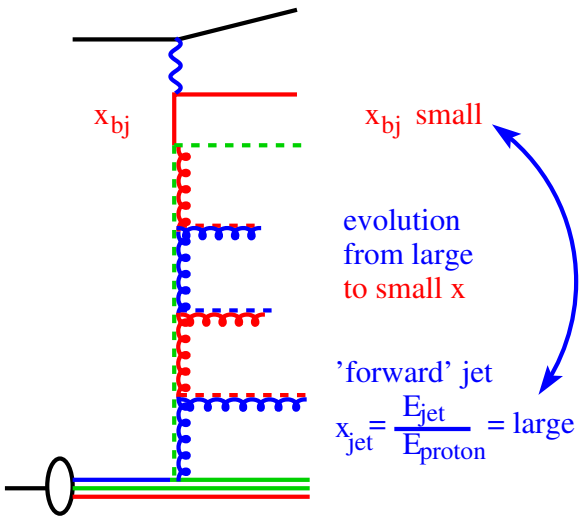


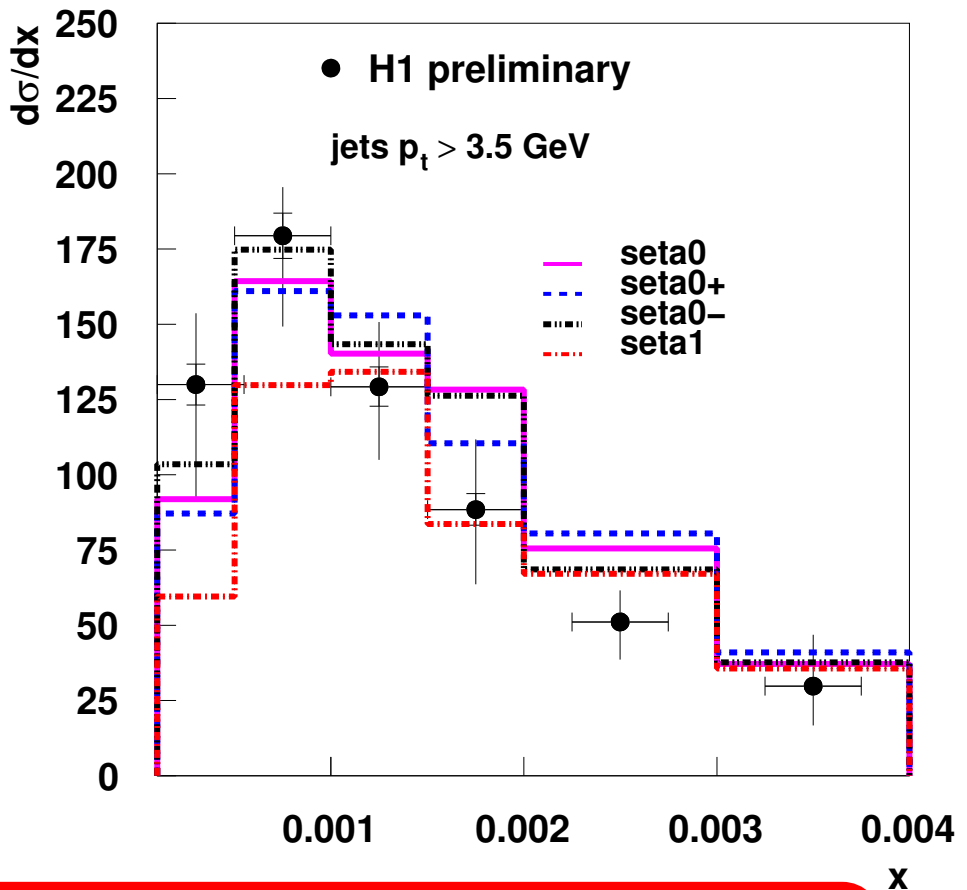
Uncertainties in x-section predictions

- Tools available for error estimates of xsect prediction
  - apply similar procedure as in collinear fact. approach
- variation of scales
  - renormalization scale
  - factorization scale
- variation of heavy quark masses
- use different parameterizations

Application I: Forward Jets



DIS : $5\ \text{GeV}^2 < Q^2 < 75\ \text{GeV}^2$
forward jet (incl. k_t algorithm)
$7^o < \theta_{jet} < 20^o$
$x_{jet} > 0.035$
$0.5 < \frac{p_{t\ jet}^2}{Q^2} < 2$



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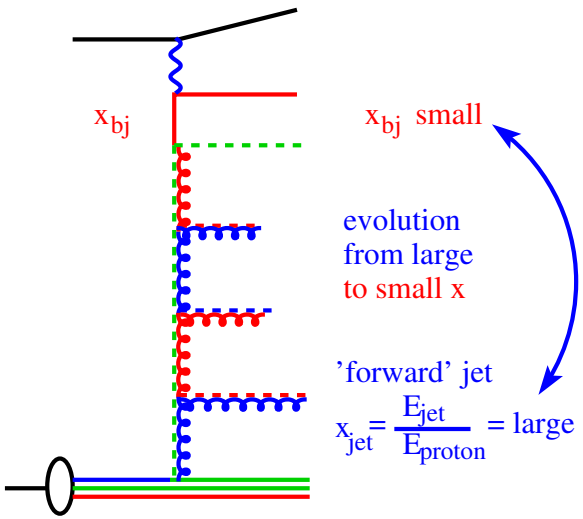

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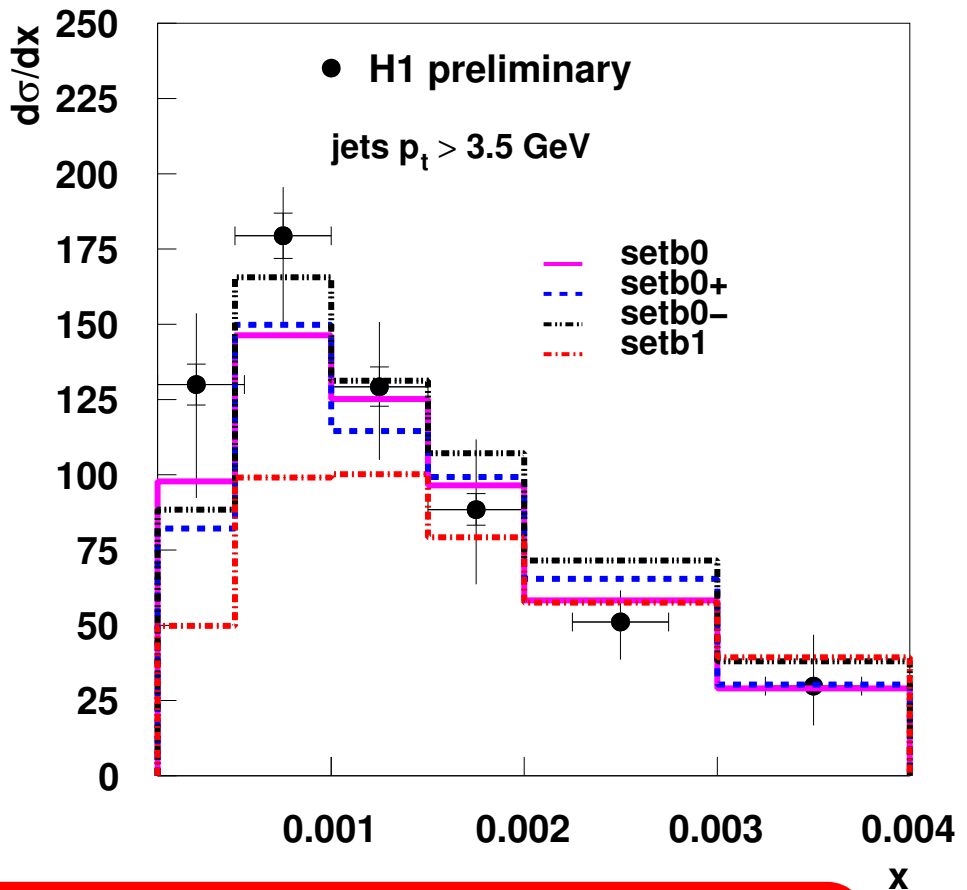

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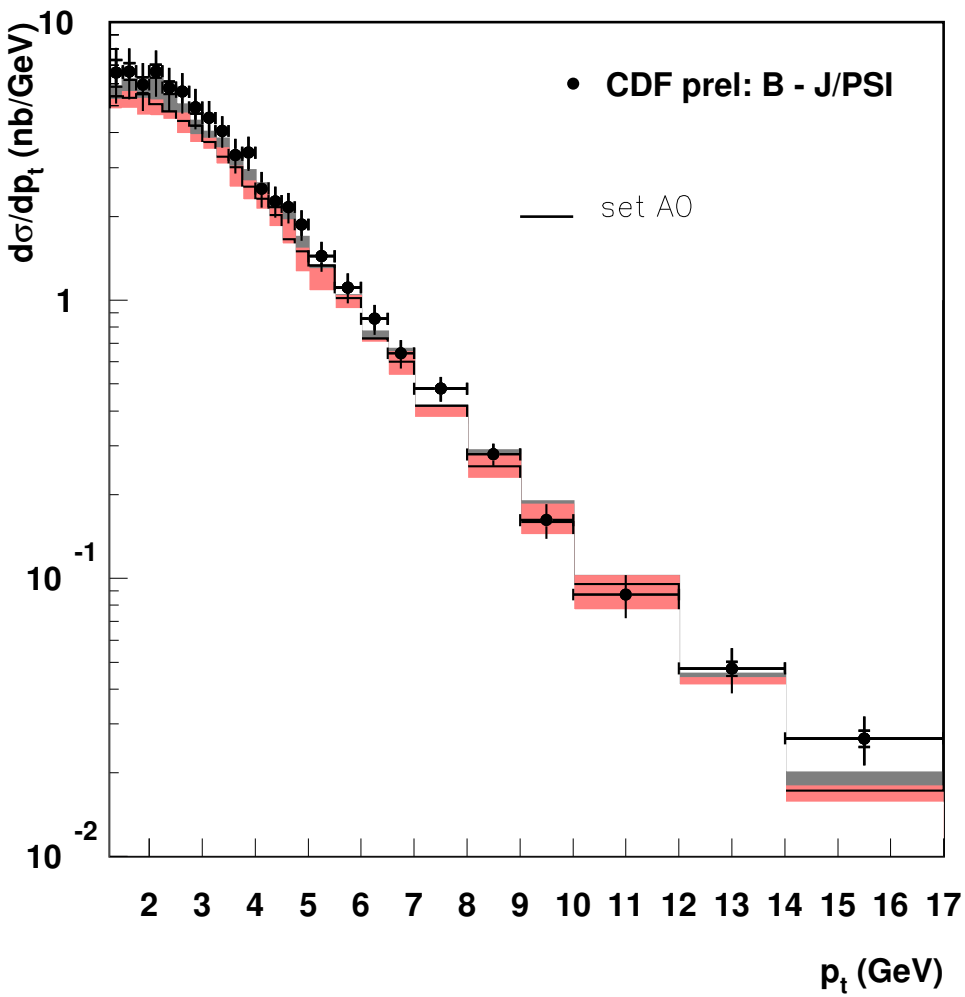
Application II: $b\bar{b}$ production at CDF: $b \to J/\psi$

Variation of:

- renorm. scale
  $0.25 p_t^2 < \mu_r^2 < 4 p_t^2$
- quark mass: $4.5 < m_b < 5$ GeV
- factorization scale

- scale uncertainties small
  including variation of b-mass
- large effect from fact. scale
  (factor ~ 2)
  is that the proper way ???



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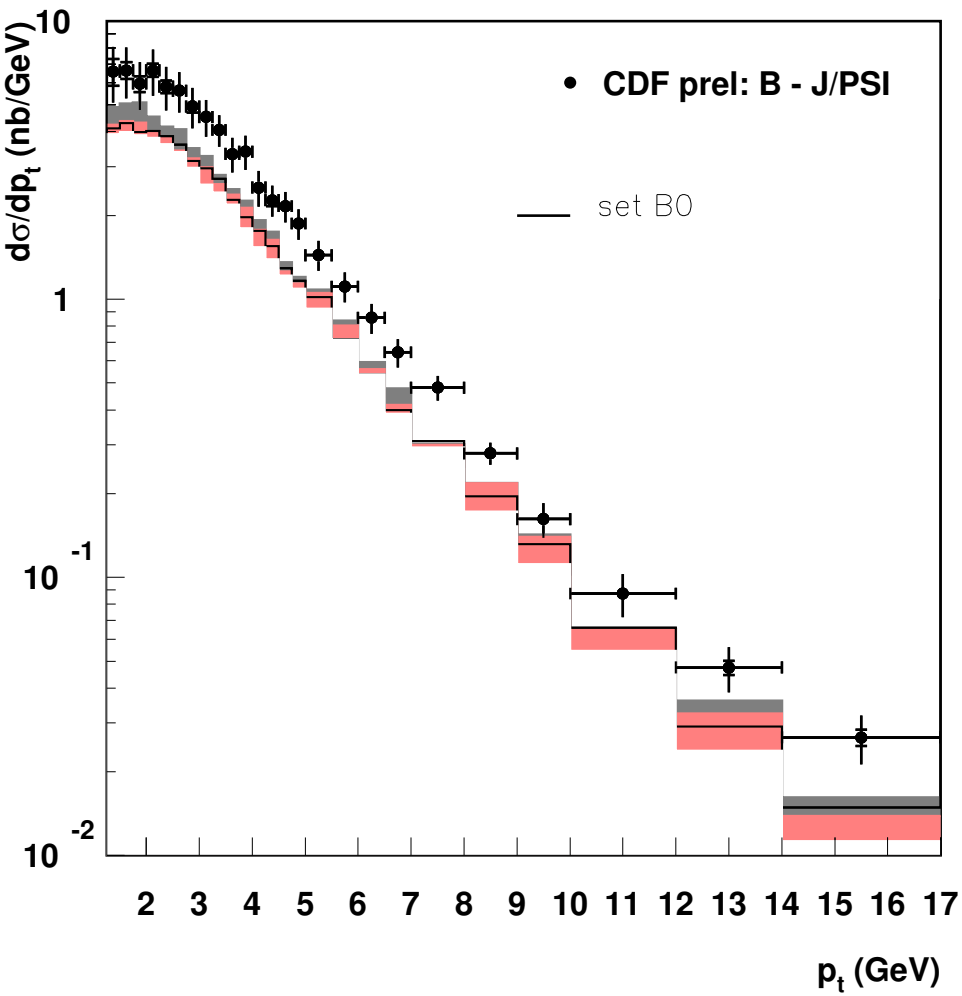
- scale uncertainties small including variation of b-mass
- large effect from fact. scale (factor ~ 2) is that the proper way ???
- large effect coming from small k_t cut !!!
- different shape of uPDF !!!



Conclusions

- watch out k_t effects
  - ➤ DGLAP: concentrated at small $< k_t >$
  - ➤ CCFM: extend to large $< k_t >$
  - ✔ HERA can contribute significantly ....
- uncertainties in uPDFs:
  - ➤ 1st steps to estimate scale uncertainties (w/o full NLO calcs.)
  - ✔ renormalization scale uncertainties ok
  - ✔ factorization scale uncertainties ????
- need for uPDFlib !!!
  - ➤ collection of uPDFs, a la PDFlib/LHAPDF, including error estimates
- global fits, including experimental errors treatment needed !!!

k_t factorization plays significant role at LHC

need for further work in uPDF sector !!!