Status of uPDF fits

H. Jung (DESY)

- Why unintegrated parton density functions (uPDFs) ?
- *The parameters of the uPDFs*
- State of the art:
  - uPDFs from *inclusive measurements*
    - ***the problem ....***
  - *uPDFs from hadronic final state measurements*
- Conclusion

Evolution of uPDFs and x-section

- unintegrated PDFs (**uPDFs**): keep full k_t dependence during perturbative evolution
  - ➔ using **D**okshitzer**G**ribov**L**ipatov**A**ltarelli**P**arisi, **B**alitski**F**adin**K**uraev**L**ipatov or **C**iafaloni**C**atani**F**iorani**M**archesini evolution equations
  - ➔ *CCFM* treats explicitly real gluon emissions
    - ➔ according to color coherence ... angular ordering
    - ➔ angular ordering includes **DGLAP** and **BFKL** as limits...
- k_t dependence in PDFs: from collinear to k_t factorization
- cross section (in k_t factorization) :

$$\frac{d\sigma^{jets}}{dE_T d\eta} = \sum \int \int \int dx_g \; dQ^2 d \ldots \left[dk_\perp^2 \, x_g \mathcal{A}_i(x_g, k_\perp^2, \bar{q}) \right] \hat{\sigma}_i(x_g, k_\perp^2)$$

  - ➔ can be reduced to the collinear limit:

$$\frac{d\sigma^{jets}}{dE_T d\eta} = \sum \int \int \int dx \; dQ^2 d \ldots x \, f_i(x, Q^2) \hat{\sigma}_i(x, Q^2, ...)$$

The parameters of uPDFs

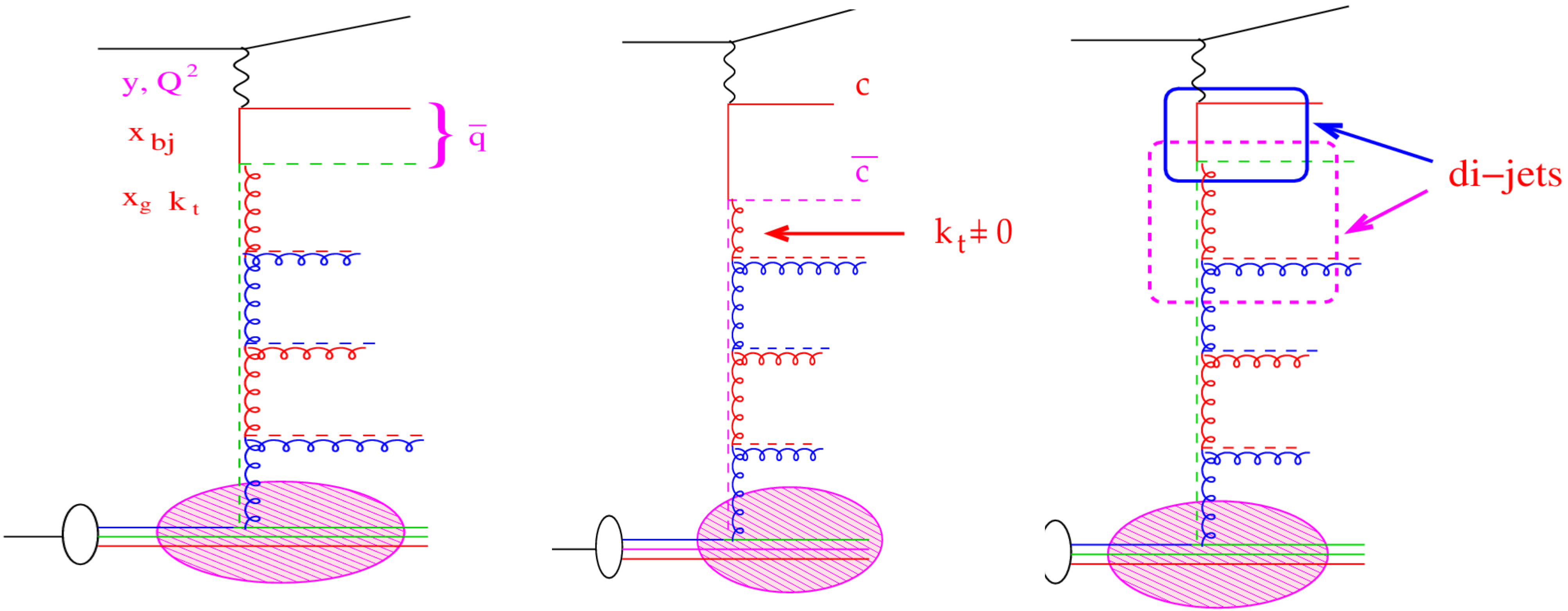
- **only gluons densities are considered *here* !!!**

$$x\mathcal{A}(x, k_\perp, \bar{q}) = \int dx_0 \mathcal{A}_0(x_0, \mu_0) \cdot \frac{x}{x_0} \tilde{\mathcal{A}}\left(\frac{x}{x_0}, k_\perp, \bar{q}\right)$$

$$x\mathcal{A}_0(x, \mu_0) = N x^{-B_g} \cdot (1-x)^4 \cdot \exp\left(-(k_{t0} - \mu)^2/\sigma^2\right)$$

- initial distribution: $\mathcal{A}_0(x_0)$
  - ➔ starting scale for evolution: here $\mu_0 = 1.2 \text{ GeV}$
  - ➔ x-dependence: parameters determined here
  - ➔ intrinsic k_t-dependence: parameters determined here
- evolution equation: here **CCFM** is used
  - ➔ splitting function: full splitting function including non-sing terms
  - ➔ α_s parameters: here $\alpha_s(M_Z) = 0.118$
  - ➔ renormalization scale: here $p_t^2 + 4m^2$
  - ➔ factorization scale: here $Q_t^2 + s$

The strategy



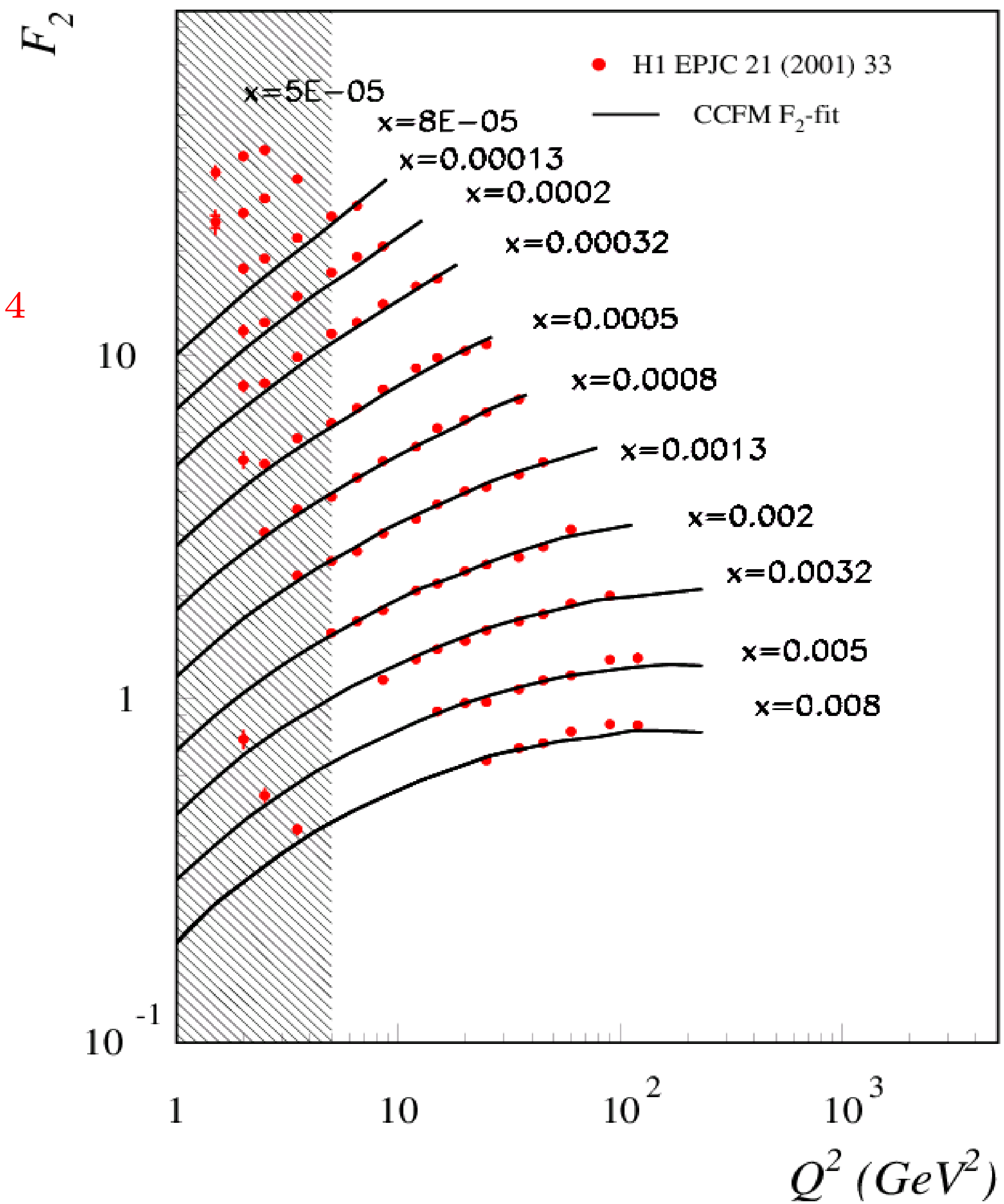
- ➔ inclusive: F_2
- ➔ x-section, normalization, x dependence, small average k_t
- ➔ fits performed

- ➔ semi-incl.: F_2^{c}, F_2^{b}
- ➔ x-dependence, larger average k_t
- ➔ fits performed .difference to F_2..

- ➔ final states
- ➔ x-dependence, differential in k_t
- ➔ NEW ... presented here

uPDF fit to F_2: x-dependence

- $$\chi^2 = \sum_i \left(\frac{(T-D)^2}{\sigma_i^{2\ stat} + \sigma_i^{2\ uncor}} \right)$$
- fit parameters of starting distribution
  $$xA_0(x,\mu_0) = Nx^{-B_g} \cdot (1-x)^4$$
- using F_2 data H1
  (H1 Eur. Phys. J. C21 (2001) 33-61, DESY 00-181)
  $$x < 0.05 \quad Q^2 > 5 \text{ GeV}^2$$
- parameters: $\mu_r^2 = p_t^2 + m_{q,Q}^2$
  $$m_q = 250\,\text{MeV}, m_c = 1.5\text{ GeV}$$
- Fit (only stat+uncorr):
  $$\frac{\chi^2}{\text{ndf}} = \frac{111.8}{61} = 1.83$$
  $$B_g = 0.028 \pm 0.003$$
  ➔ similar to DGLAP fits (~1.5)



uPDF fit to F_2^c: x-dependence

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- fit parameters of starting distribution

$$xA_0(x,\mu_0) = N x^{-B_g} \cdot (1-x)^4$$

- using F_2^c data H1

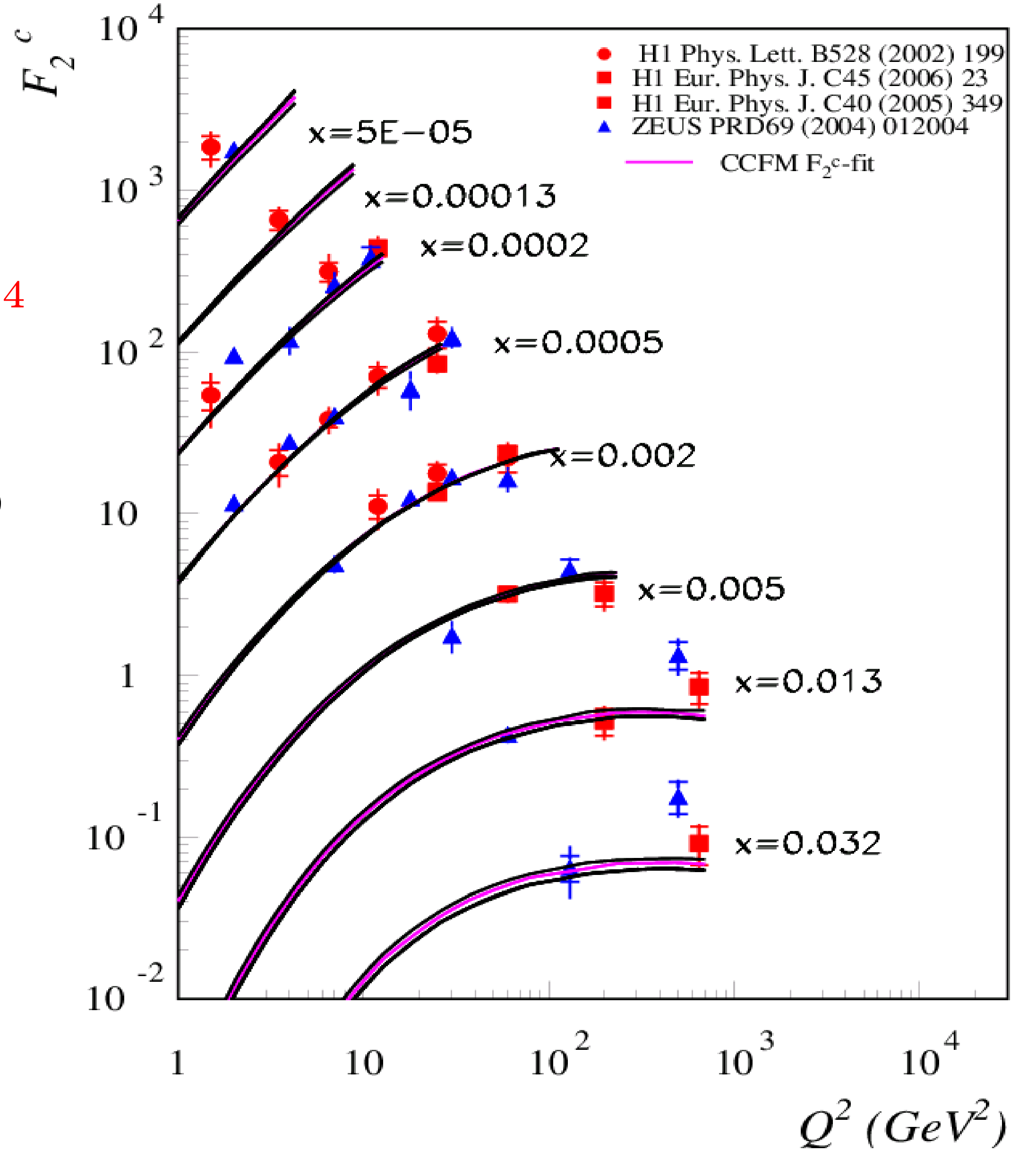
(H1 PLB528 (2002) 199, EPJC 40 (2005) 349 ,EPJC45 (2006) 23)

$$Q^2 > 1\ \mathrm{GeV}^2$$

- fit result: $\frac{\chi^2}{\mathrm{ndf}} = \frac{18.8}{20} = 0.94$

with $B_g = 0.286 \pm 0.002$

➔ higher than for F_2 !?!?!?!



$\lambda = 0.088$

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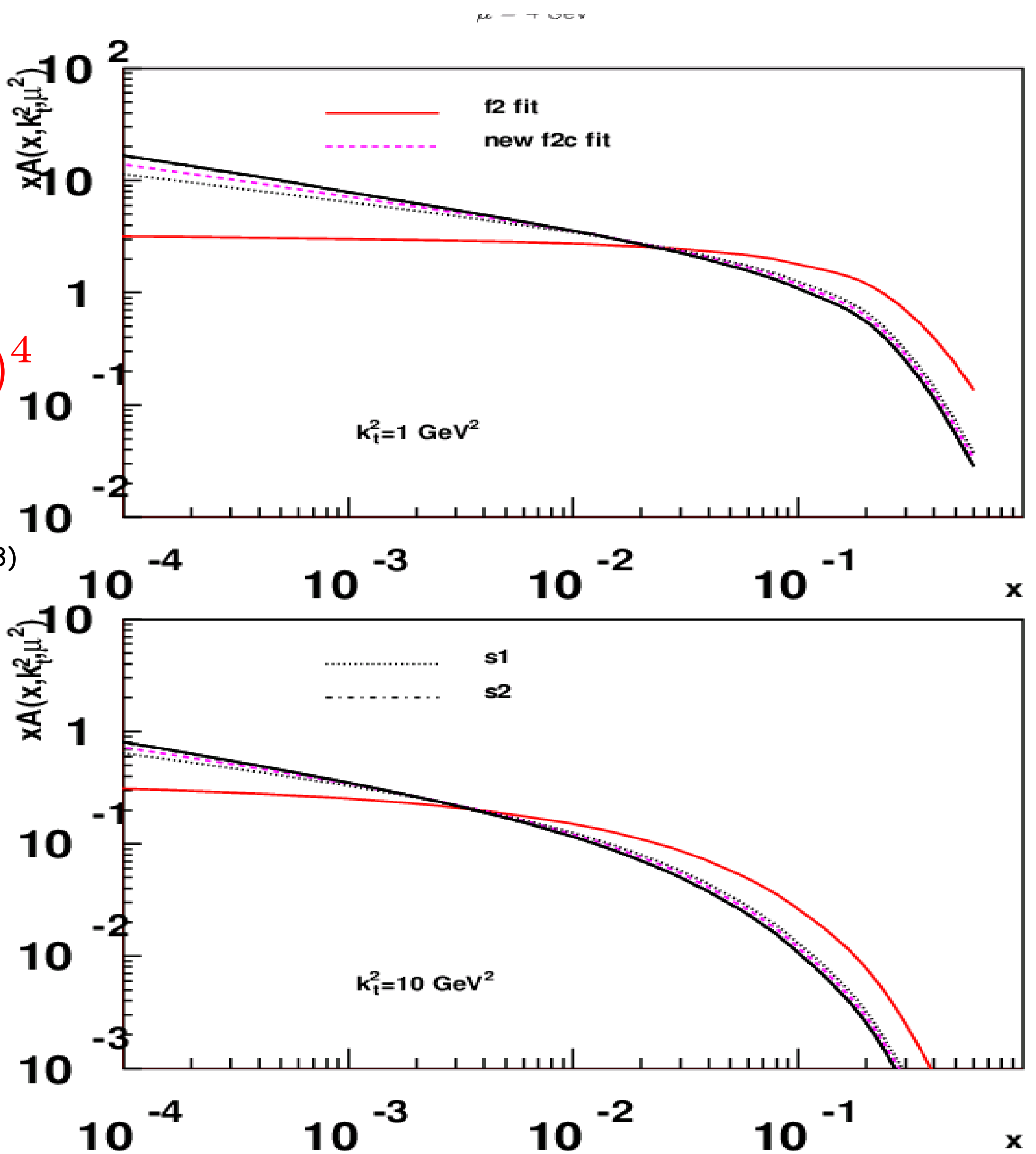
➔ significant change of uPDF

➔ .... not covered by uncertainty obtained from exp uncertainties



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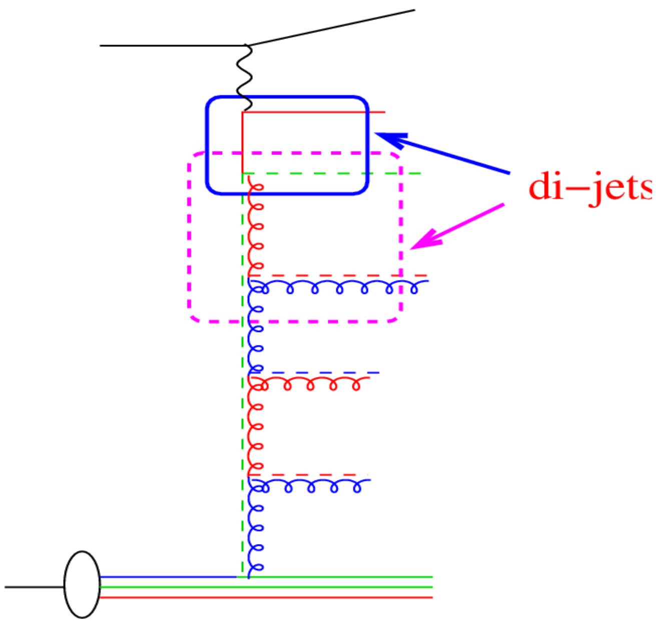
How to resolve discrepancy ?

check with other measurements:

➔ DIS di-jet cross sections

uPDFs from di-jets: x-dependence



- Using H1 jet measurements

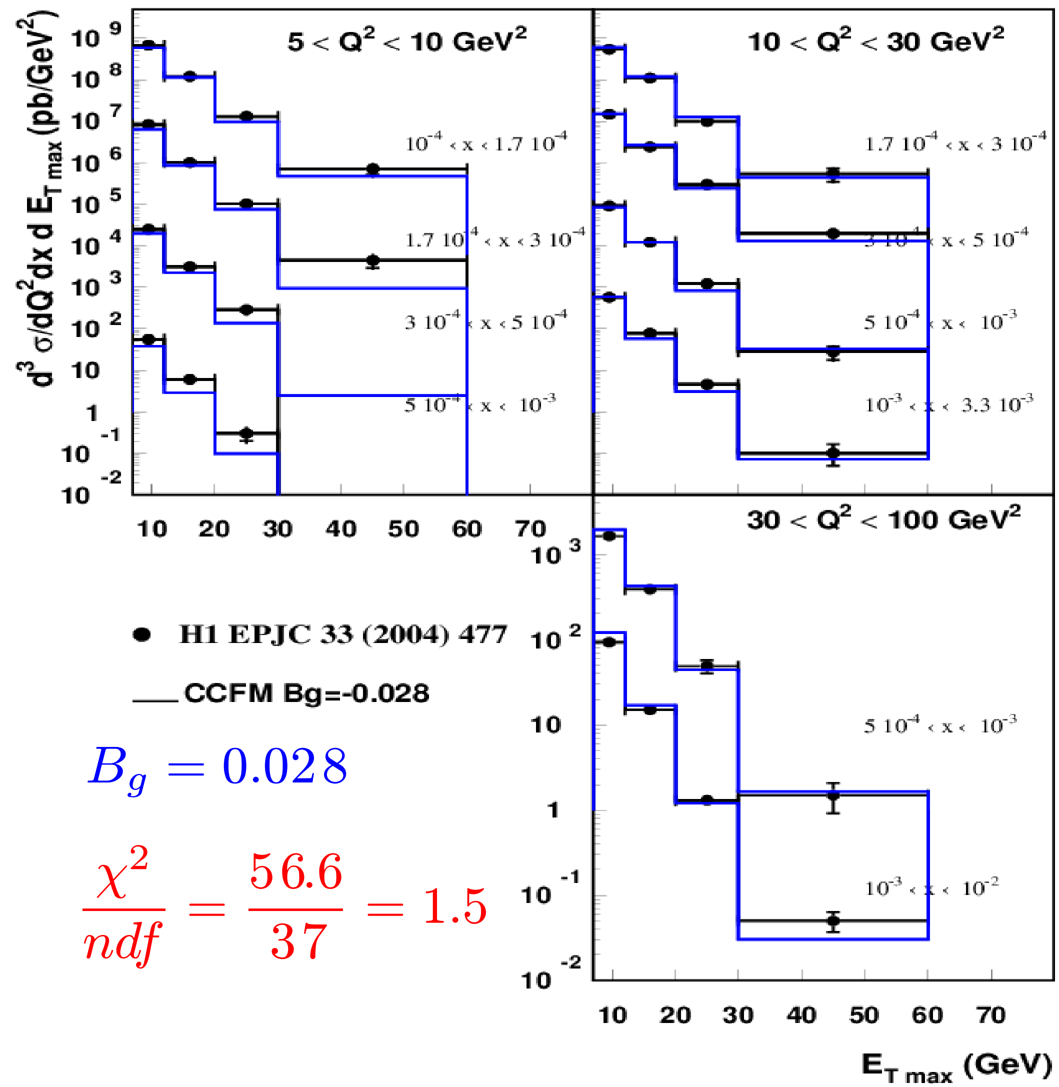
(H1 EPJC 33 (2004) 477)

$$5 < Q^2 < 100\ \mathrm{GeV}^2$$
$$-1 < \eta < 2.5$$
$$E_T > 5\ \mathrm{GeV}$$

- investigate x- and k_t- dependence of starting dist.

- x dependence with $\dfrac{d^3\sigma}{dE_T^{max}\,dx\,dQ^2}$

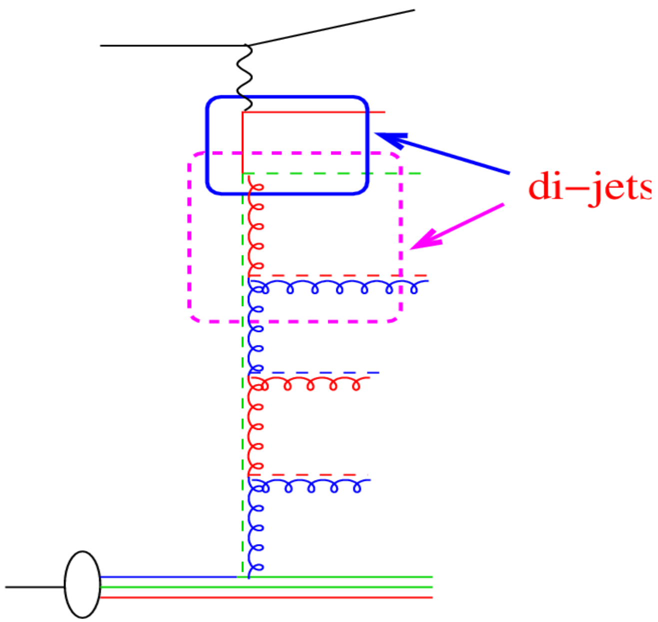
$$x\mathcal{A}_0(x,\mu_0) = N x^{-B_g}\cdot(1-x)^4$$



$$B_g = 0.028$$

$$\frac{\chi^2}{ndf} = \frac{56.6}{37} = 1.5$$

uPDFs from di-jets: x-dependence



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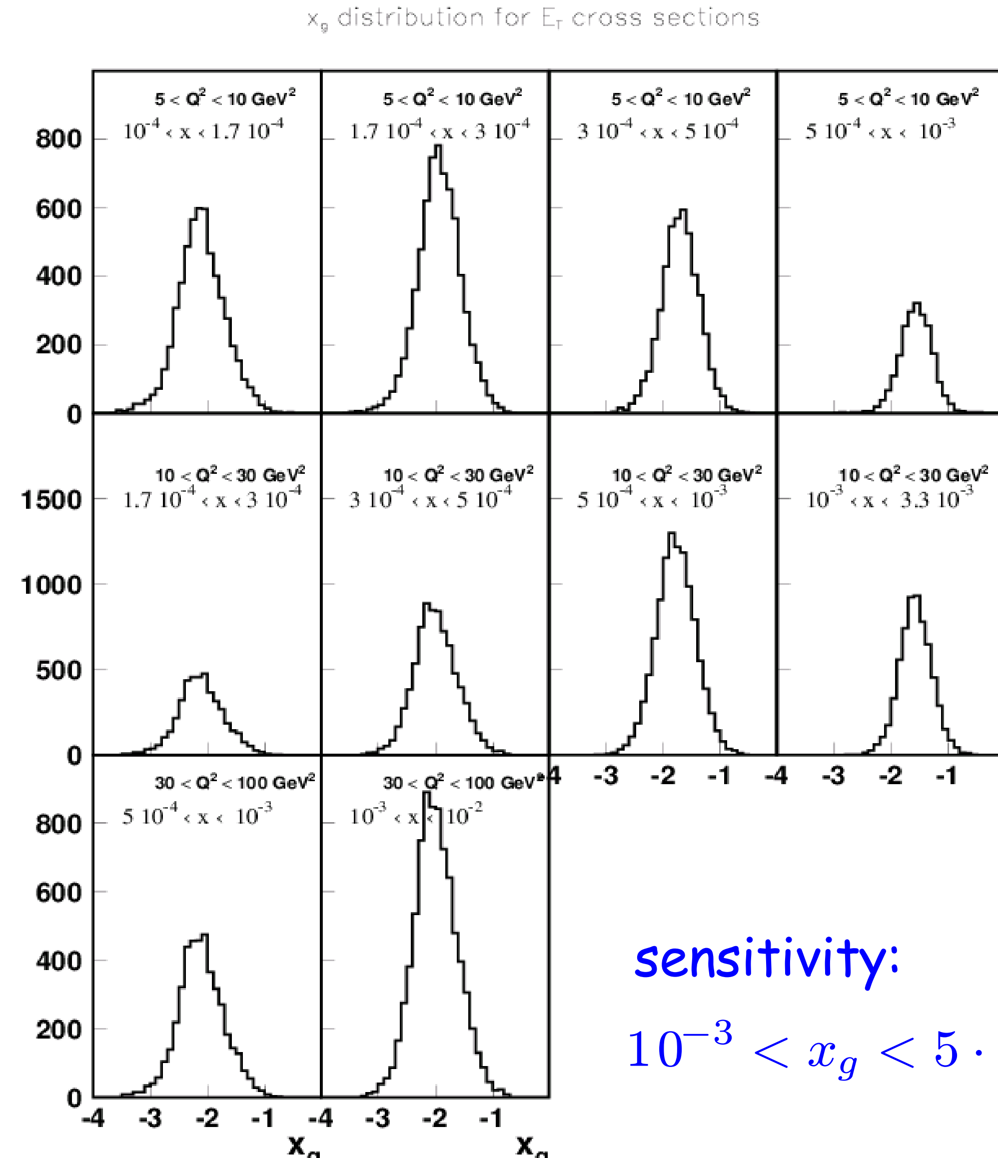

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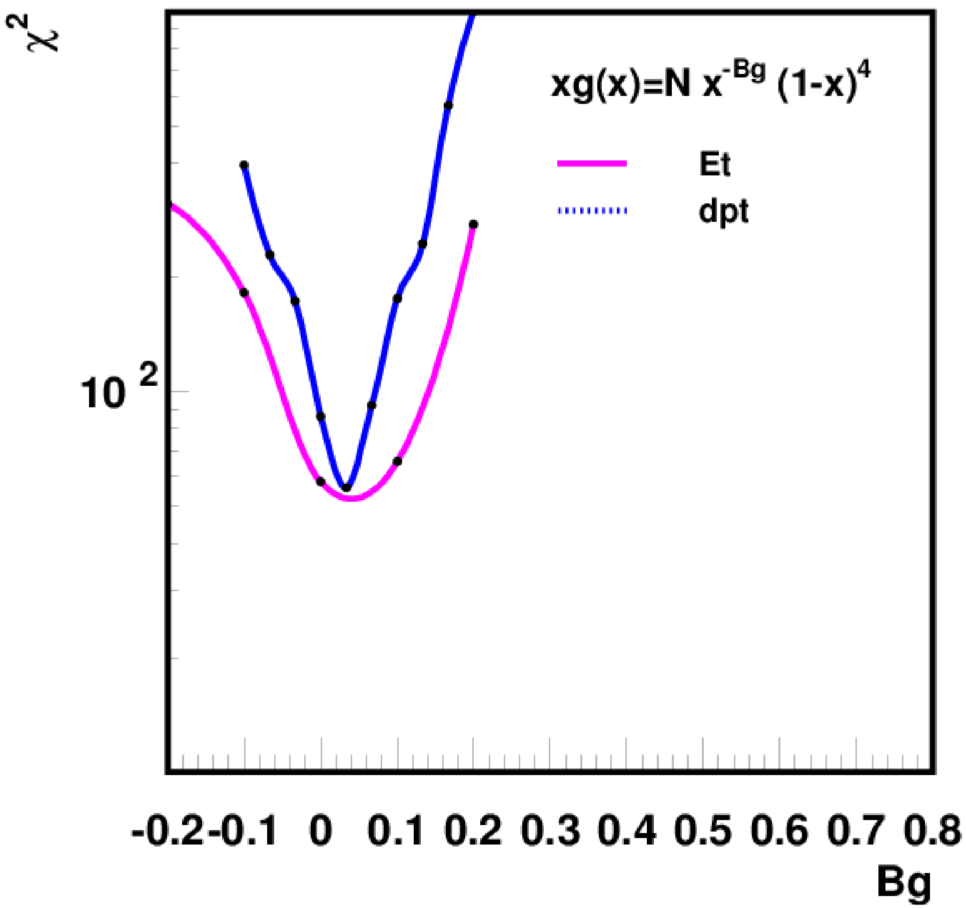
sensitivity:

$$10^{-3} < x_g < 5 \cdot 10^{-1}$$

uPDFs from di-jets: x-dependence

- Determination of B_g:

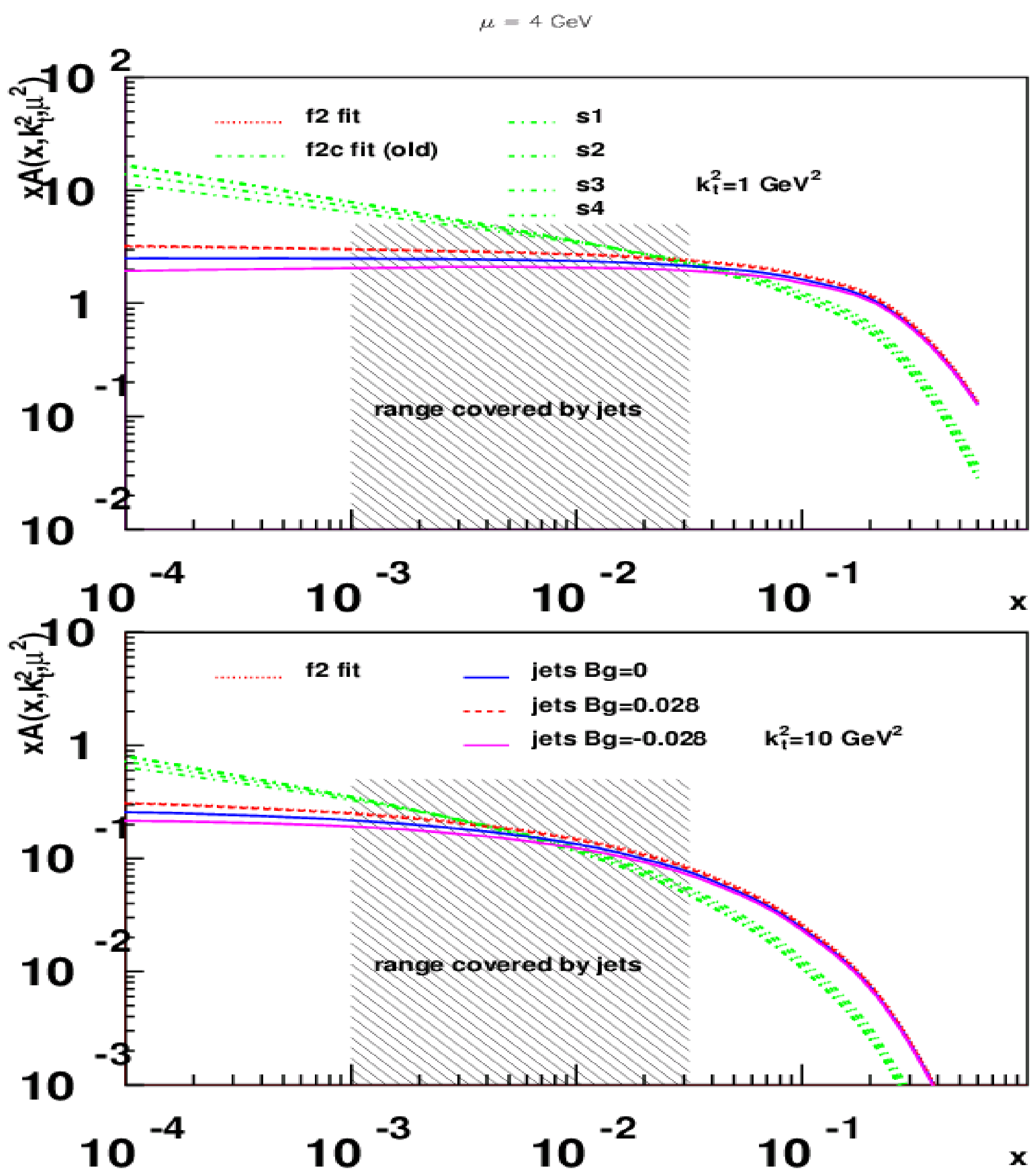
$$xA_0(x,\mu_0) = Nx^{-B_g} \cdot (1-x)^4$$



➔ very similar to F_2 gluon !

➔ even in normalization !!!

- resulting gluon distribution:



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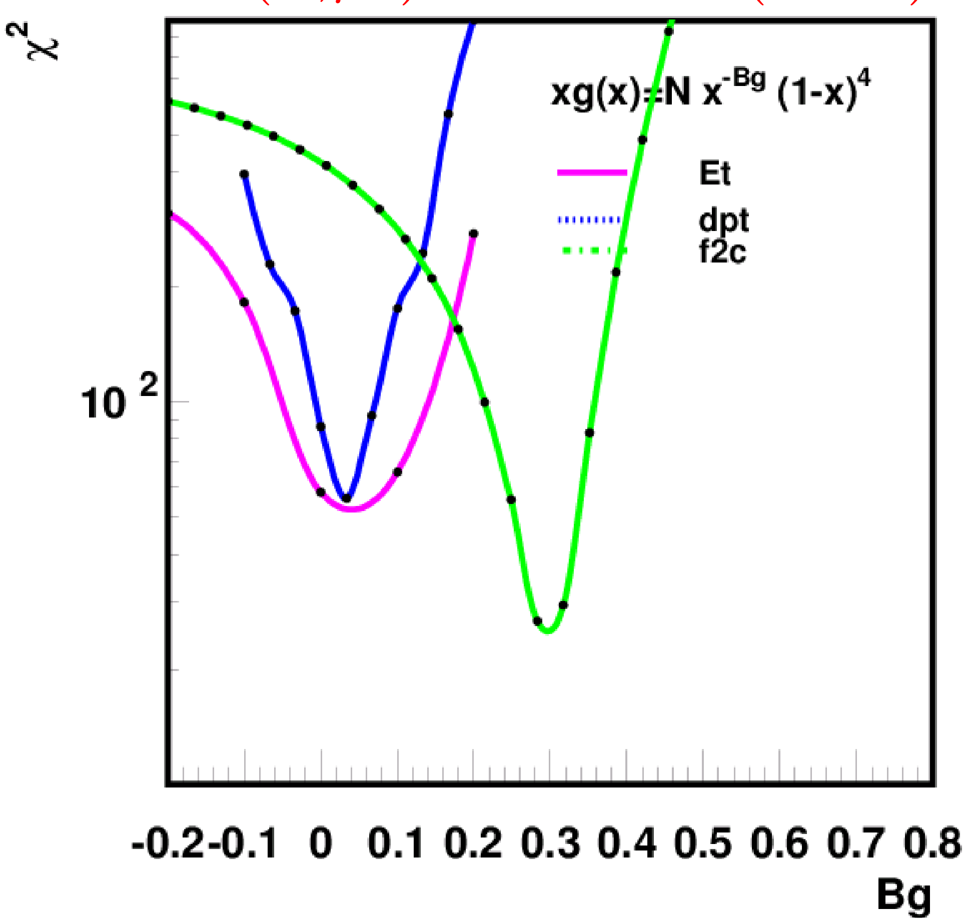

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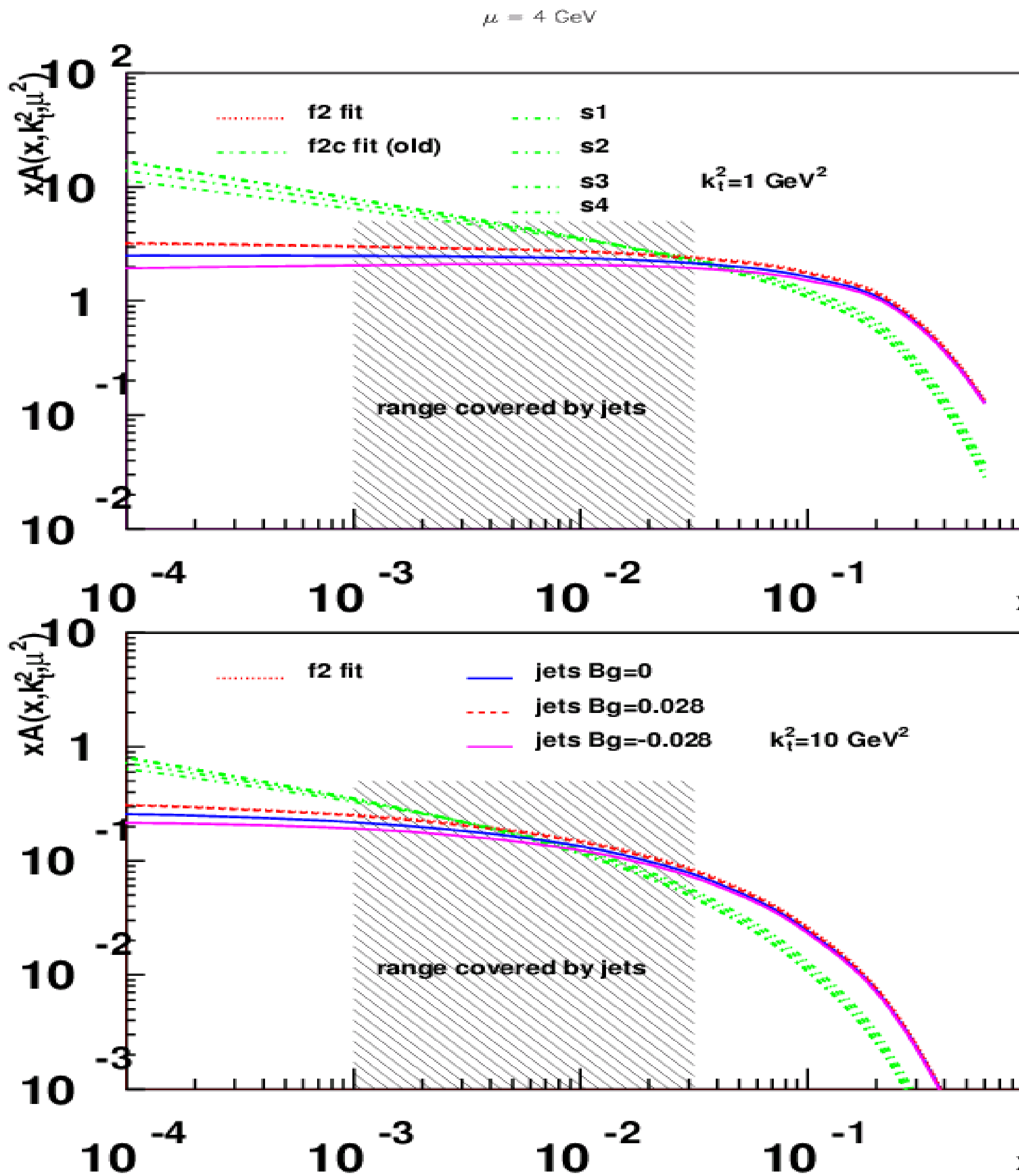

How to resolve discrepancy with F_2^c?

- check other measurements:
  - F_2^b, F_L (see talk by N.Zotov in SF)
  - F_2^b clearly prefers F_2 solution:
    - using F_2 fit: $\frac{\chi^2}{ndf} = \frac{7.4}{8} = 0.92$
    - using F_2^c fit: $\frac{\chi^2}{ndf} = \frac{16.7}{8} = 2.1$
  - hadronic final states:
    - DIS di-jet cross sections
    - ➔ also prefer a F_2 like gluon !!!!
  - investigate F_2^c again
    - ➔ rise of gluons comes from lowest x points

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    - ➔ also prefer a F_2 like gluon !!!!
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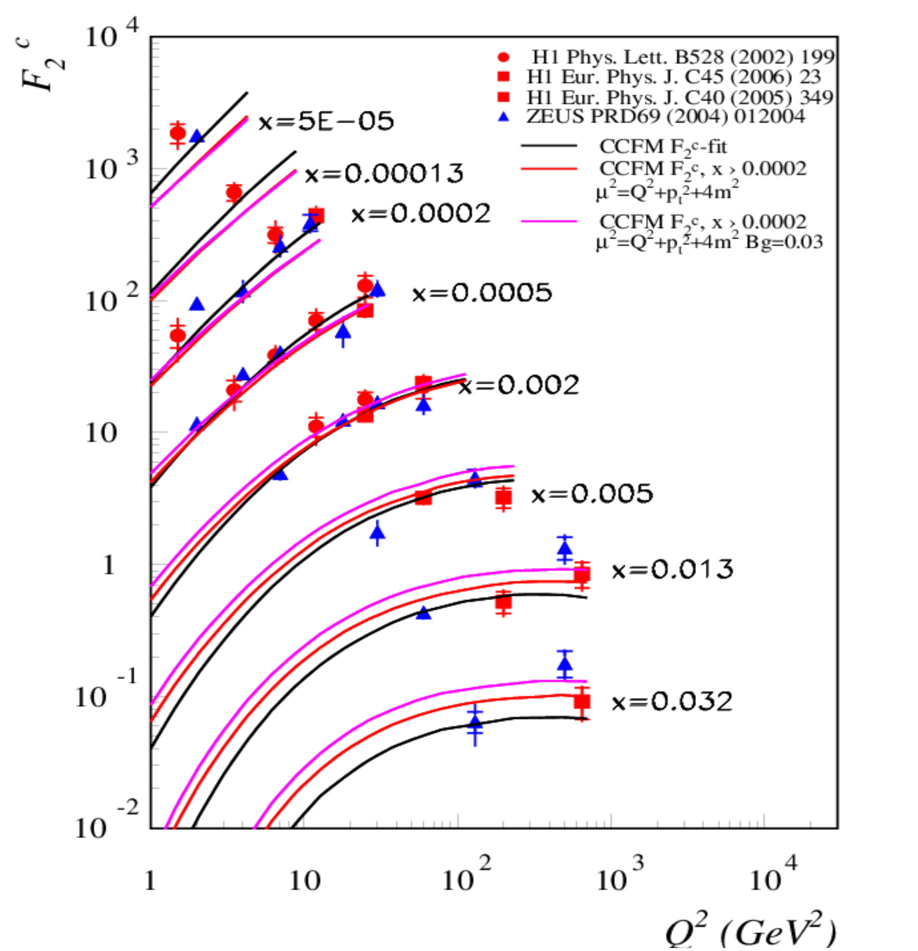
- restrict fit to x> 0.0002 gives for

  $x\mathcal{A}_0(x,\mu_0) = Nx^{-B_g} \cdot (1-x)^4$

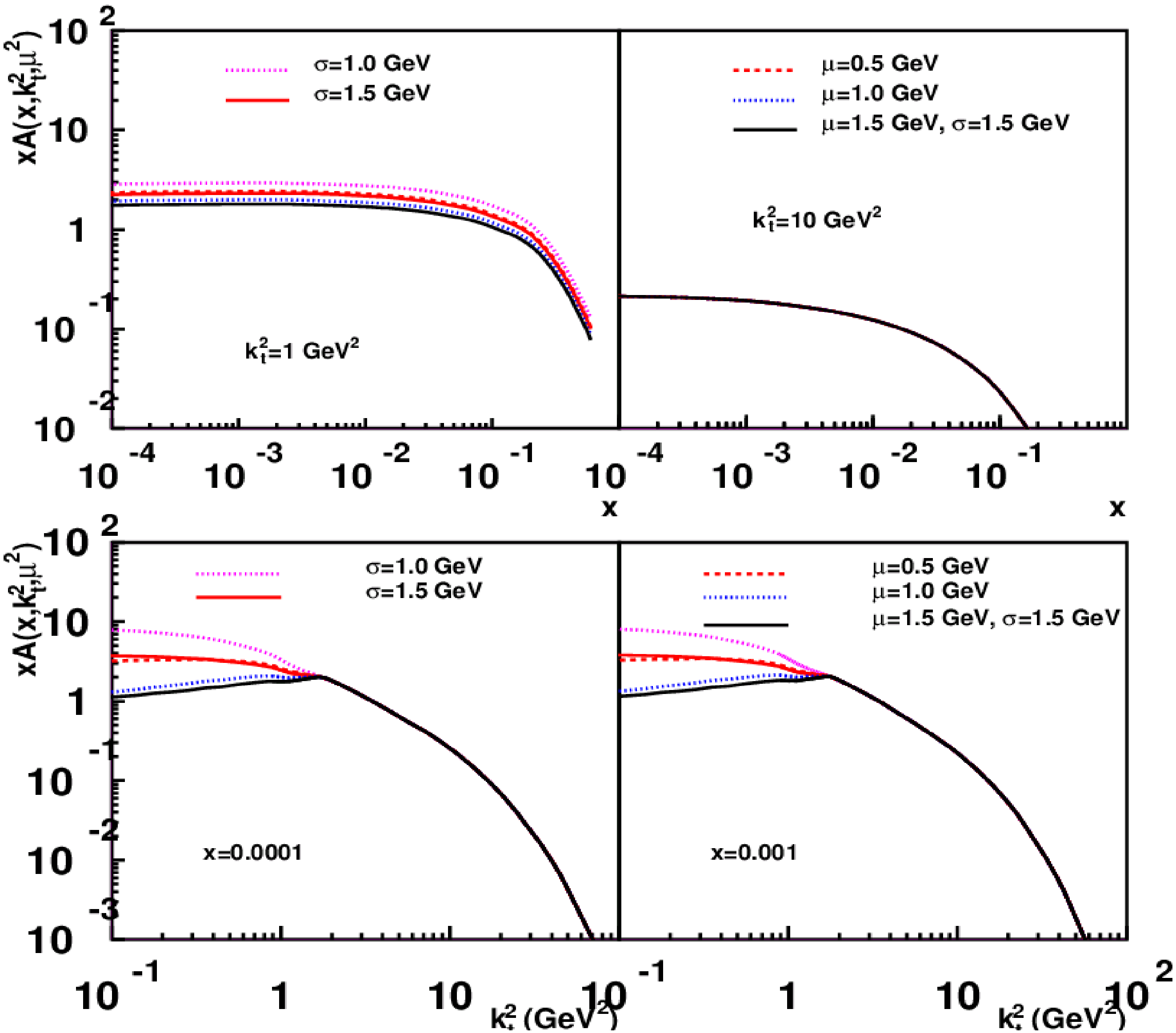
  $B_g = 0.15$ and $\chi^2/ndf = 0.8$
- even $B_g = 0.028$ gives $\chi^2/ndf = 1.1$



uPDFs from di-jets: intrinsic k_t

$$x\mathcal{A}(x,\mu_0^2) = N x^{-B_g} \cdot (1-x)^4 \cdot \exp\left(-(k_{t0}-\mu)^2/\sigma^2\right)$$

μ = 4 GeV

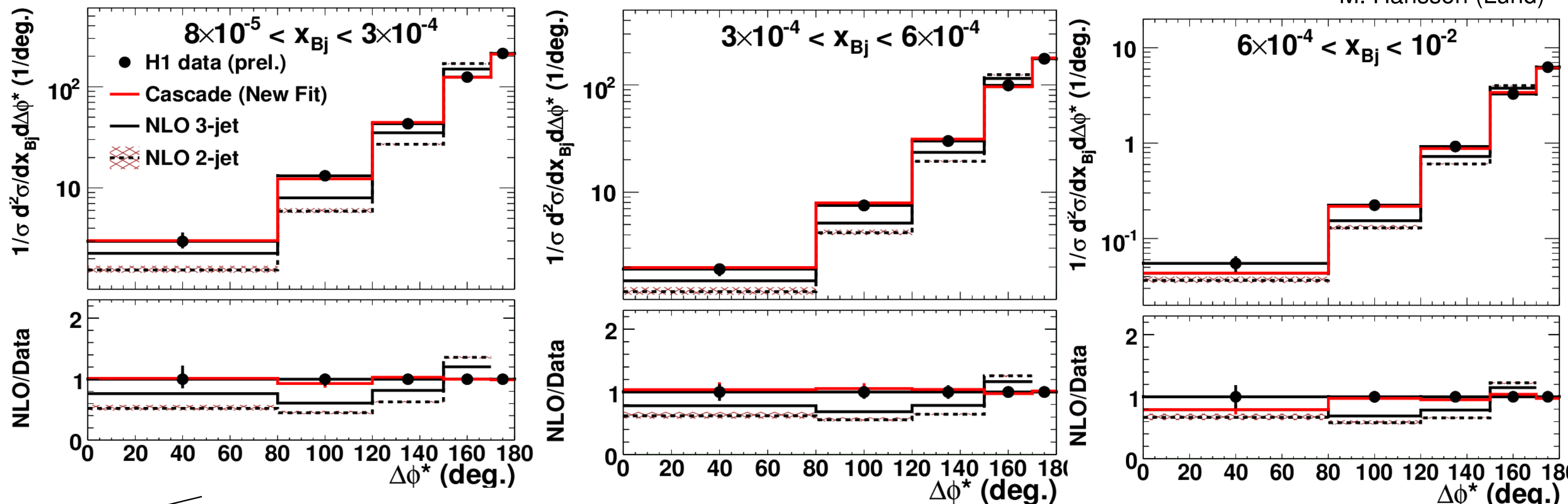


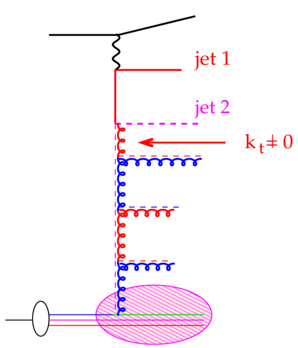
- different intrinsic k_t-distributions only accessible in uPDFs
- sensitive to the mix of small and large k_t
  - ➔ small kt determines total x-section
  - ➔ large kt influences perturbative tails ...

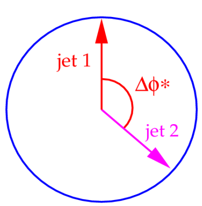
uPDFs from di-jets: k_t-dependence

- k_t dependence with $\frac{1}{\sigma}\frac{d^2\sigma}{d\Delta\phi^*\, dx}$, with $x\mathcal{A}(x,\mu_0^2) = N x^{-B_g}\cdot(1-x)^4 \cdot \exp\left(-(k_{t0}-\mu)^2/\sigma^2\right)$

M. Hansson (Lund)







- H1 prel data

$5 < Q^2 < 100\ \mathrm{GeV}^2$

$-1 < \eta < 2.5$

$E_T > 5\ \mathrm{GeV}$

- intrinsic gauss:

$\sigma \sim 1.5$

$\mu \sim 1.5$

- 1st direct determination of intrinsic k_t distribution
- consistent with gauss... but other distributions not excluded

Conclusion

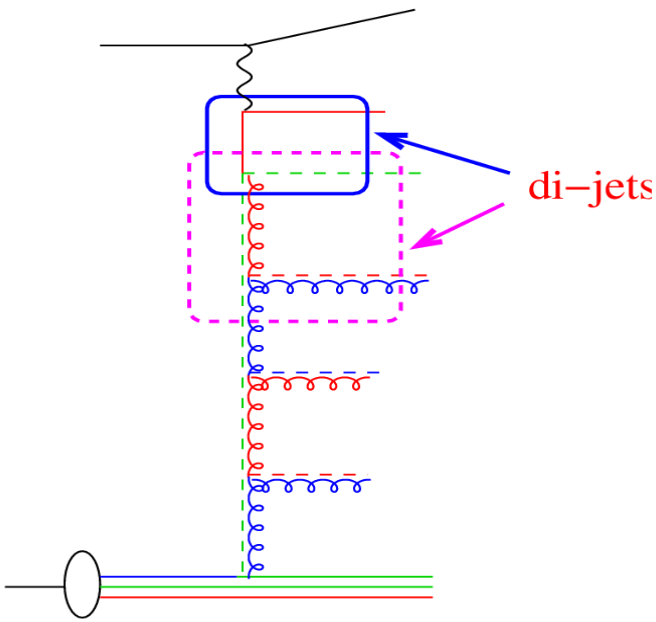
- Full treatment of kinematics in calculations is necessary – NEED **uPDFs**
  - NLO corrections are MUCH smaller then ....
    - ➔ **uPDFs** are needed for precision calculations at LHC: ... see heavy quarks, Higgs etc ...
- ***Determination of free parameters of uPDFs:***
  - *x- dependence:*
    - *from F_2 ,F_2^c* and jets is consistent with a flat gluon distribution
    - ➔ except smallest x points in F_2^c
  - *k_t – dependence:*
    - ➔ consistent with a gauss with mean ~ 1.5 and width of ~ 1.5 GeV
    - ➔ **1st direct and independent determination of intrinsic k_t distribution**
- *Towards precision fits:*
  - ➔ *combination of F_2 and jets, uncertainties ... to come ...*

➔ **uPDFs become fascinating ......**

with many applications !!!!!!!

Backup slides

uPDFs from di-jets: x-dependence



- Using H1 jet measurements

  (H1 EPJC 33 (2004) 477)

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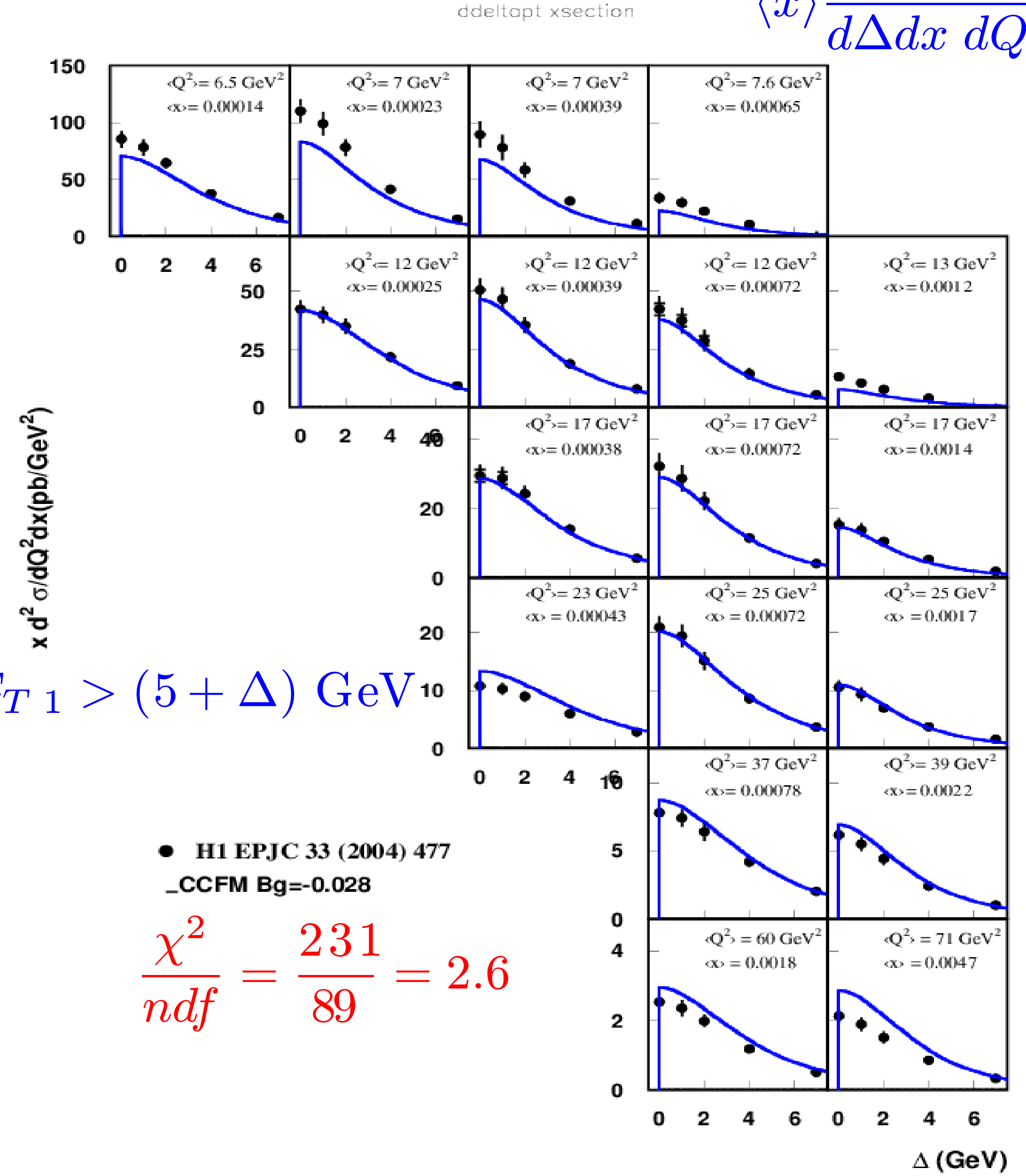
  $$E_T > 5\ \mathrm{GeV}$$

- investigate x- and k_t-dependence of starting dist.

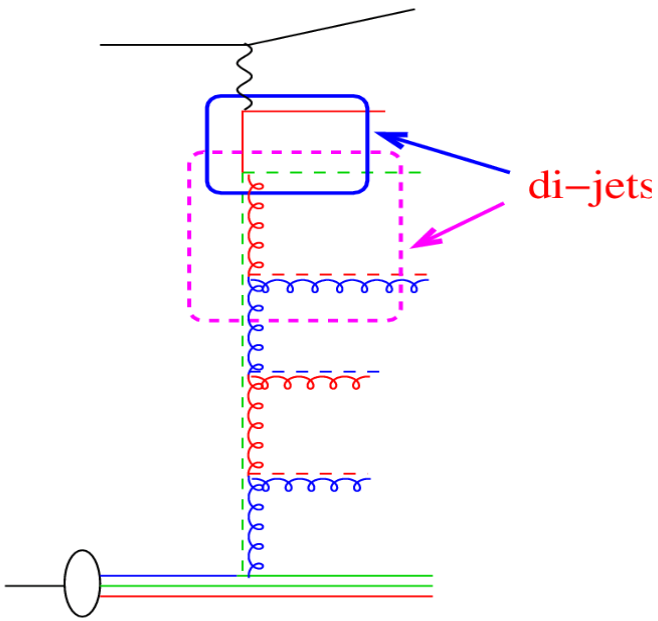
- x dependence with $\langle x \rangle \frac{d^2\sigma}{d\Delta dx\, dQ^2}$

$$E_{T\,1} > (5 + \Delta)\ \mathrm{GeV}$$

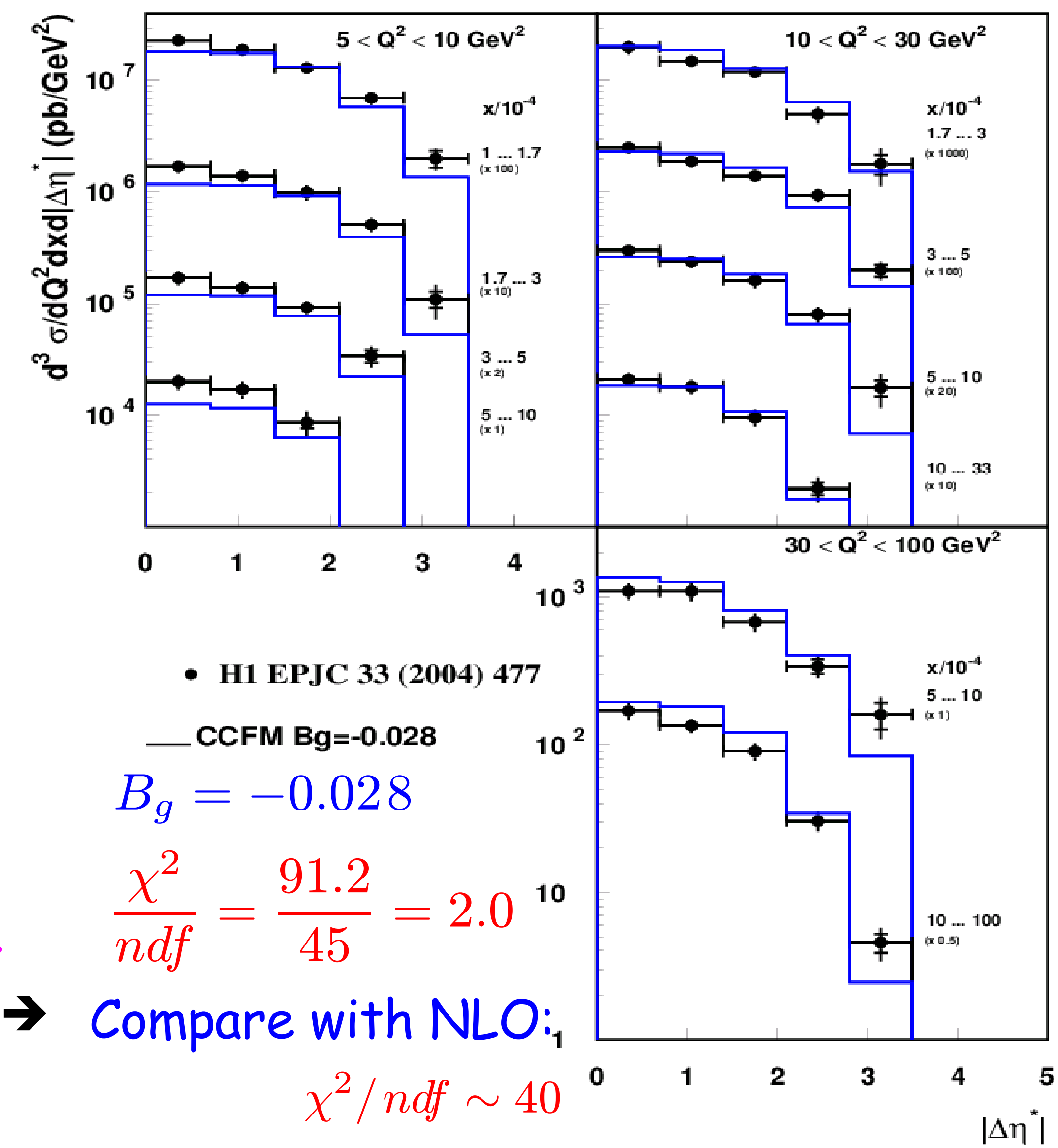


$$\frac{\chi^2}{ndf} = \frac{231}{89} = 2.6$$

uPDFs from di-jets: x-dependence



- x dependence with $\frac{d^3\sigma}{d|\Delta\eta| dx\, dQ^2}$



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- investigate x- and k_t- dependence of starting dist.

$$B_g = -0.028$$

$$\frac{\chi^2}{ndf} = \frac{91.2}{45} = 2.0$$

➔ Compare with NLO: $\chi^2/ndf \sim 40$

uPDFs from di-jets: k_t-dependence

- k_t dependence with $\frac{d^2\sigma}{d\Delta\phi^*\, dx}$, with $x\mathcal{A}(x,\mu_0^2) = N x^{-B_g} \cdot (1-x)^4 \cdot \exp\left(-(k_{t0}-\mu)^2/\sigma^2\right)$

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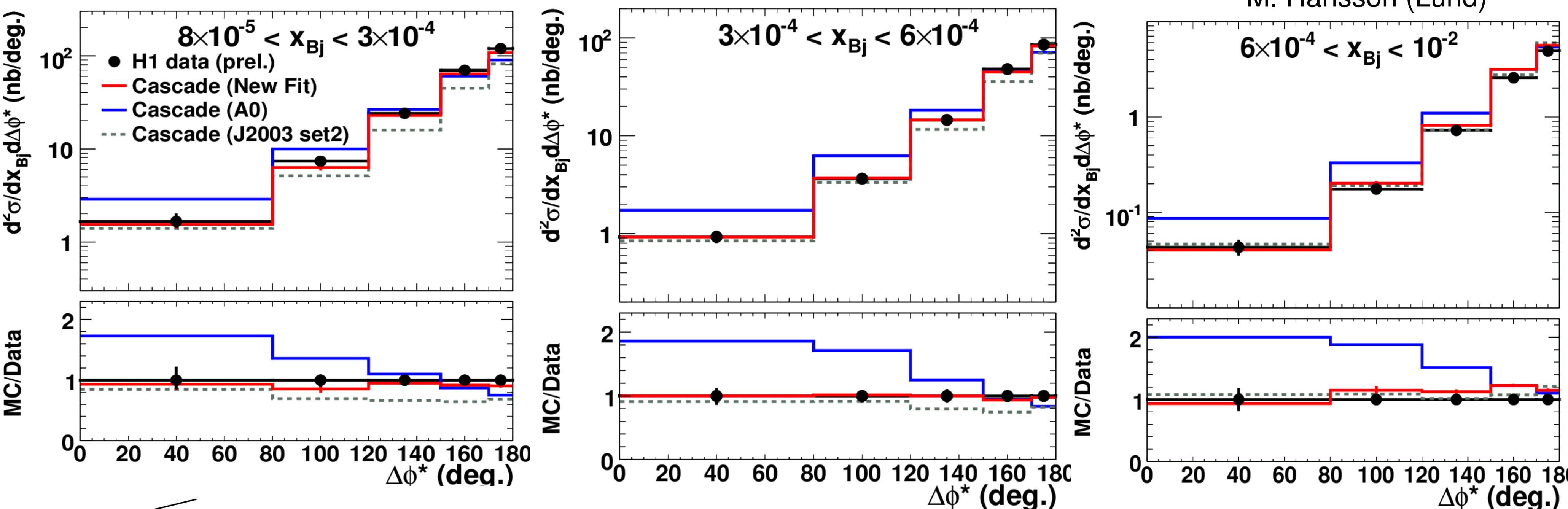

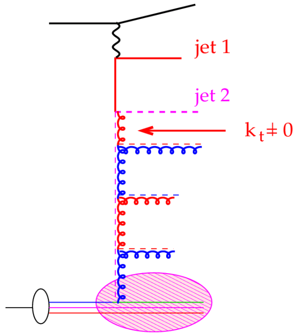

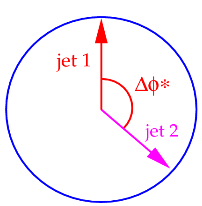

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