# Top-quark cross-section using the gluon-distribution from boson-gluon fusion

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*Thanks to Hannes Jung*

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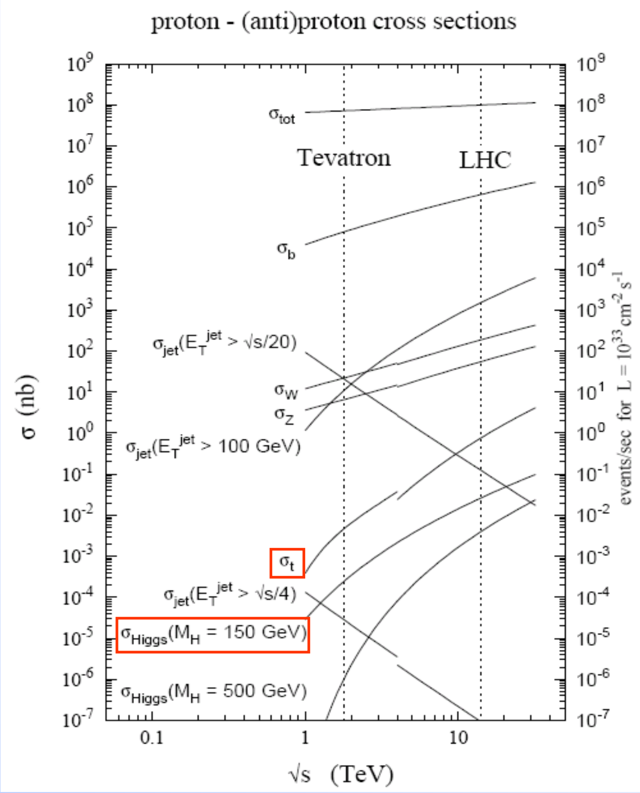
# Motivation

- At the LHC Higgs-boson is produced dominantly in gluon-gluon fusion
- Production of top-quark pairs (85% from $g\,g \rightarrow t\,\bar{t}$)

➢ **Precise knowledge of proton structure necessary!**




- General partonic substructure of the proton:

$\Rightarrow$ Parton-density functions $f_i\,(x,\mu^2)$ (PDFs)

  - Bjorken scaling variable x
  - Renormalization scale $\mu$

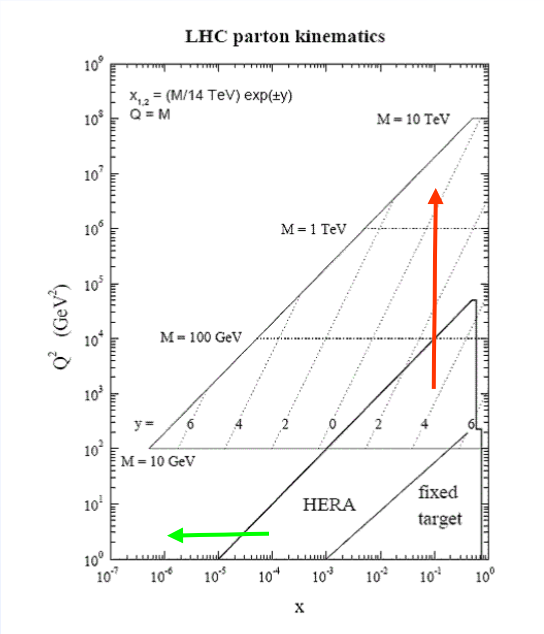
- Experimentally constrained from fits to the

proton structure function $F_2\,(x,\mu^2)$

extracted from the measurements of inclusive deep-inelastic scattering (DIS) cross-section at HERA from $e^{\pm}\,p \rightarrow e^{\pm}\,X$.

# Evolution equations I: $D_{okshitzer}G_{ribov}L_{ipatov}A_{ltarelli}P_{arisi}$

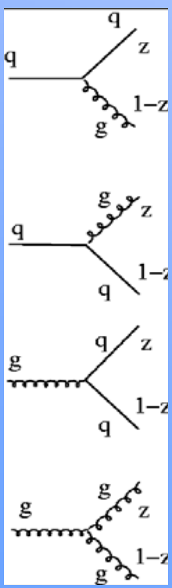
$\partial F_2(x,Q^2)/\partial\mu^2 = 0$




- Energy scale dependence of the PDFs:

  $\rightarrow$ measured PDFs at fixed $\mu_0$: $f_i\,(x,(\mu_0)^2)$

- DGLAP evolution equation ($\mu^2 = Q^2$):




$$\frac{\partial}{\partial \ln(Q^2)} f_i(x,Q^2) = \frac{\alpha_S(Q^2)}{2\pi}\int_x^1 \frac{dy}{y}\left(P_{qq}(\tfrac{x}{y})\, f_i(y,Q^2) + P_{qg}(\tfrac{x}{y})\, g(y,Q^2)\right)$$

with splitting functions $P_{qq}(z) = \frac{4}{3}\left(\frac{1+z^2}{1-z}\right)$ and $P_{qg}(z) = \frac{1}{2}\left(z^2 + (1-z)^2\right)$

give the probability for a quark with momentum fraction y to radiate a gluon, keeping momentum x.

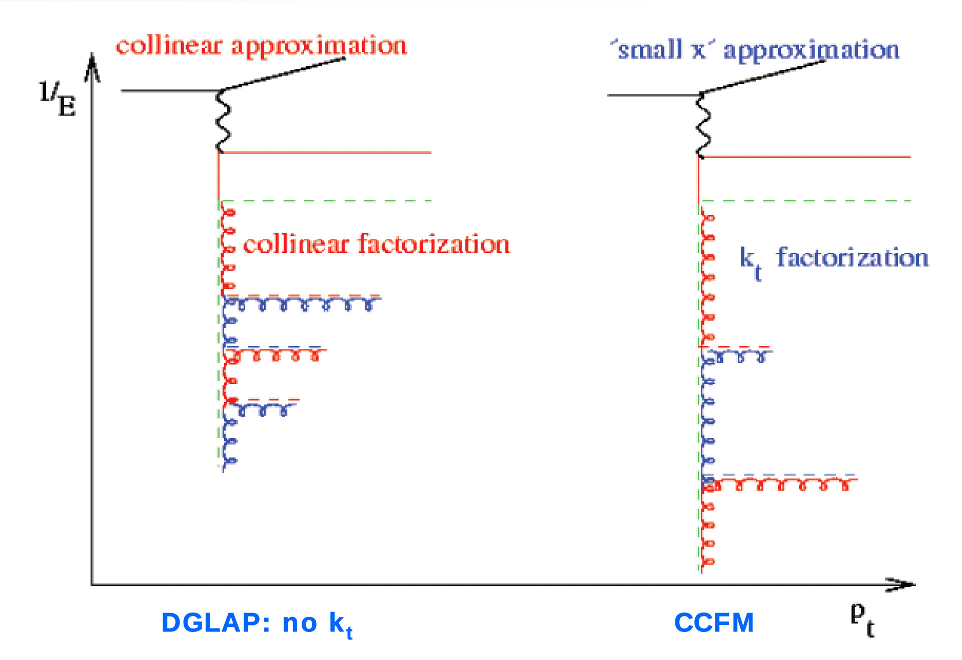
- Gluon density function:

$$\frac{\partial g(x,\mu^2)}{\partial \ln(\mu^2)} = \frac{\alpha_S}{2\pi}\int_x^1 \frac{dy}{y}\left[\sum_i q_i(y,\mu^2) P_{gq}(\tfrac{x}{y}) + g(y,\mu^2) P_{gg}(\tfrac{x}{y})\right]$$

# Evolution equations II: $C_{atani}C_{iafaloni}F_{iorani}M_{archesini}$

- DGLAP ⇔ CCFM:

  ⇒ Collinear to $k_t$-factorization



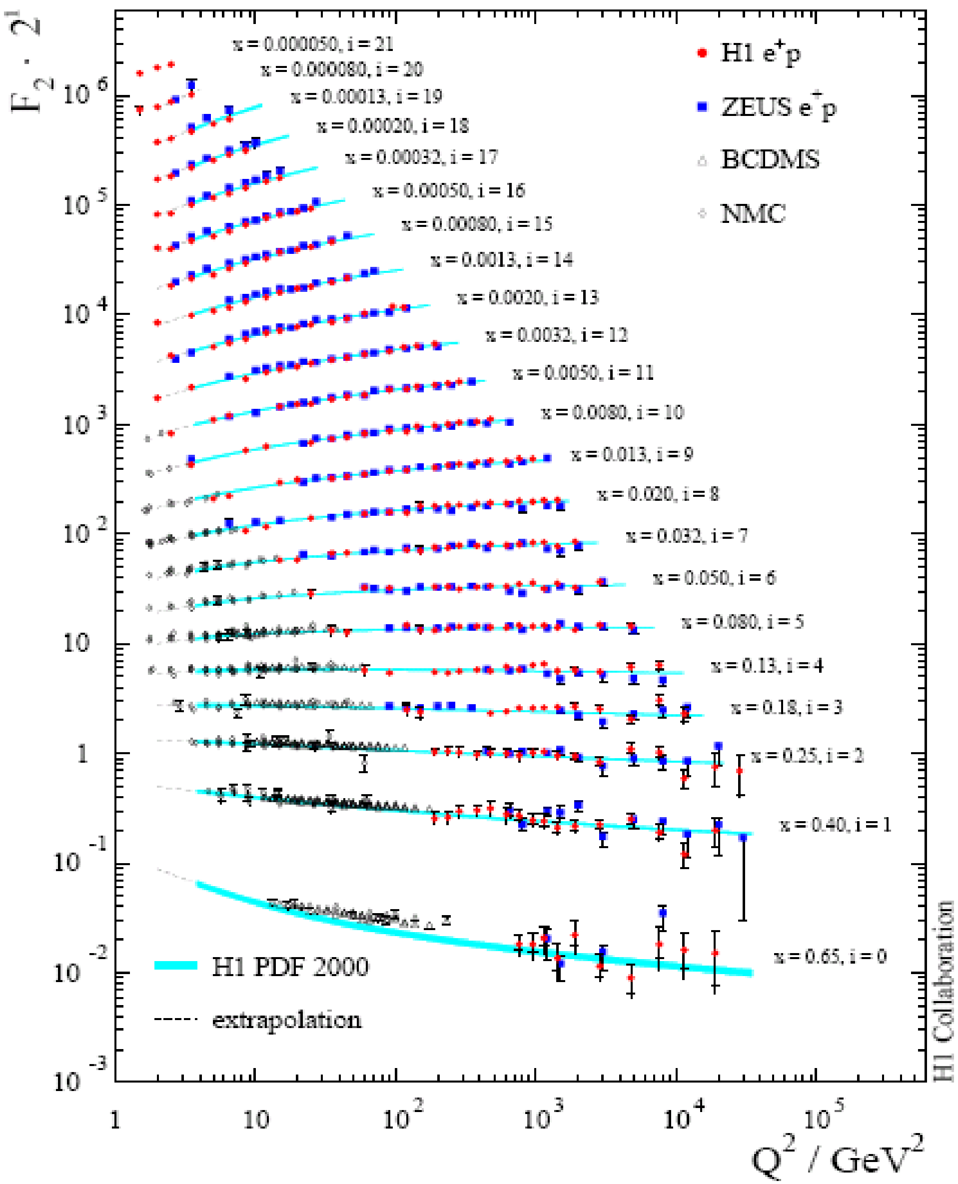

- Expansion towards 'small x':

  → using $k_\perp$-dependent, unintegrated PDFs (uPDFs) $\mathcal{A}(x, k_\perp, Q)$

  e.g. gluon-uPDF:
$$x\, g(x,Q) = \int \frac{d^2 k_\perp}{\pi}\, x\, A(x, k_\perp, Q)\, \theta(Q - k_\perp)$$

- CCFM evolution equations include large and small x!

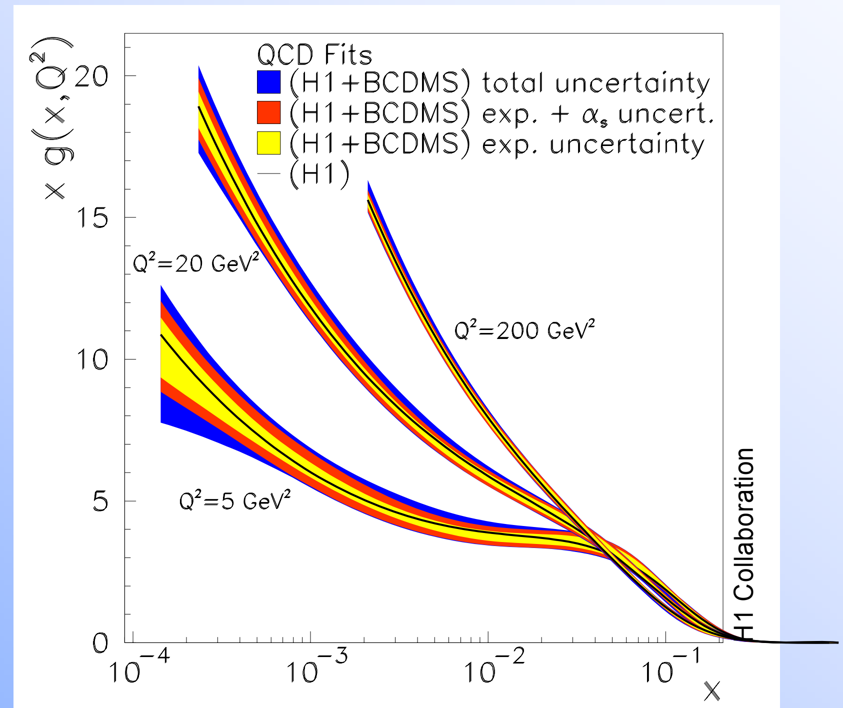
# Inclusive $F_2$ measurements at HERA




**<u>*ep* kinematics: √s = 318 GeV</u>**

- 4-momentum transfer squared $Q^2 = -q^2$
- Bjorken scaling variable $x = Q^2/(2qP)$

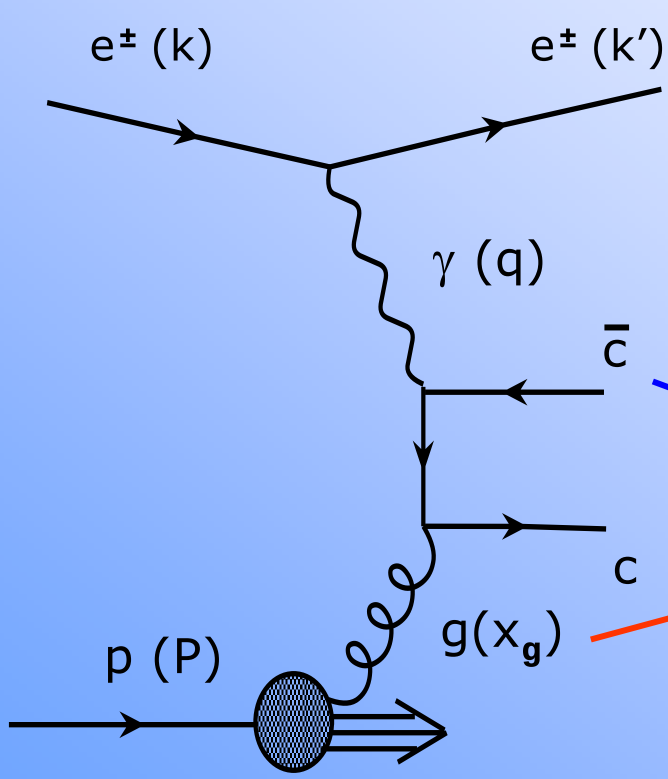
- Scaling violation of $F_2(x, Q^2)$
- Extracting gluon distribution




Inclusive measurement:
unknown initial parton distributions

# Heavy flavour production at HERA

Dominated by boson–gluon fusion (BGF) in LO: $\gamma\, g \rightarrow c\bar{c}\ (b\bar{b})$




- Measure charm-production cross-section via cross-section of D*-production
- Extract charm-contribution $F^c_2$ to proton structure function $F_2$

Charmed meson (D*)

gluon directly involved → constrain $g(x_g)$

$$F_2^{c\ \mathrm{LO}} \propto \int \frac{dx'}{x'} e_c^2\, g(x_g, \mu^2)\, \sigma_{c\bar{c}}(x, \mu)$$

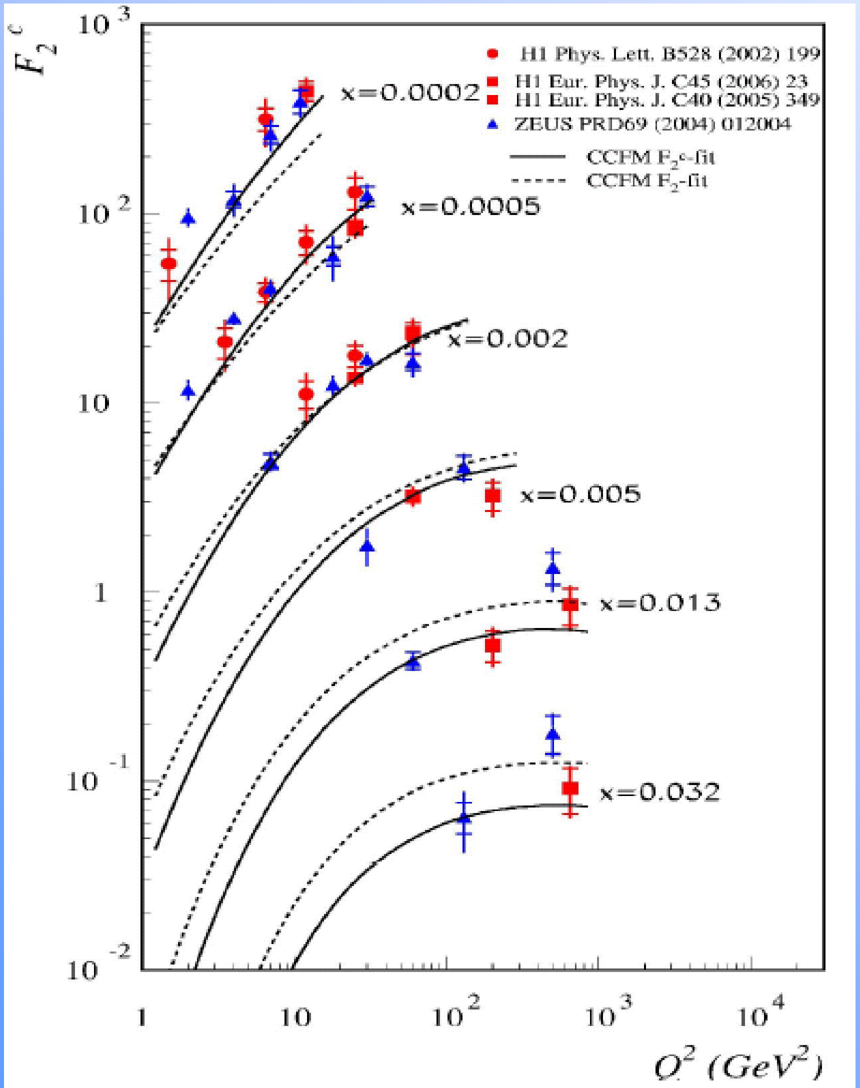
- Important cross-check of the gluon from inclusive measurements!

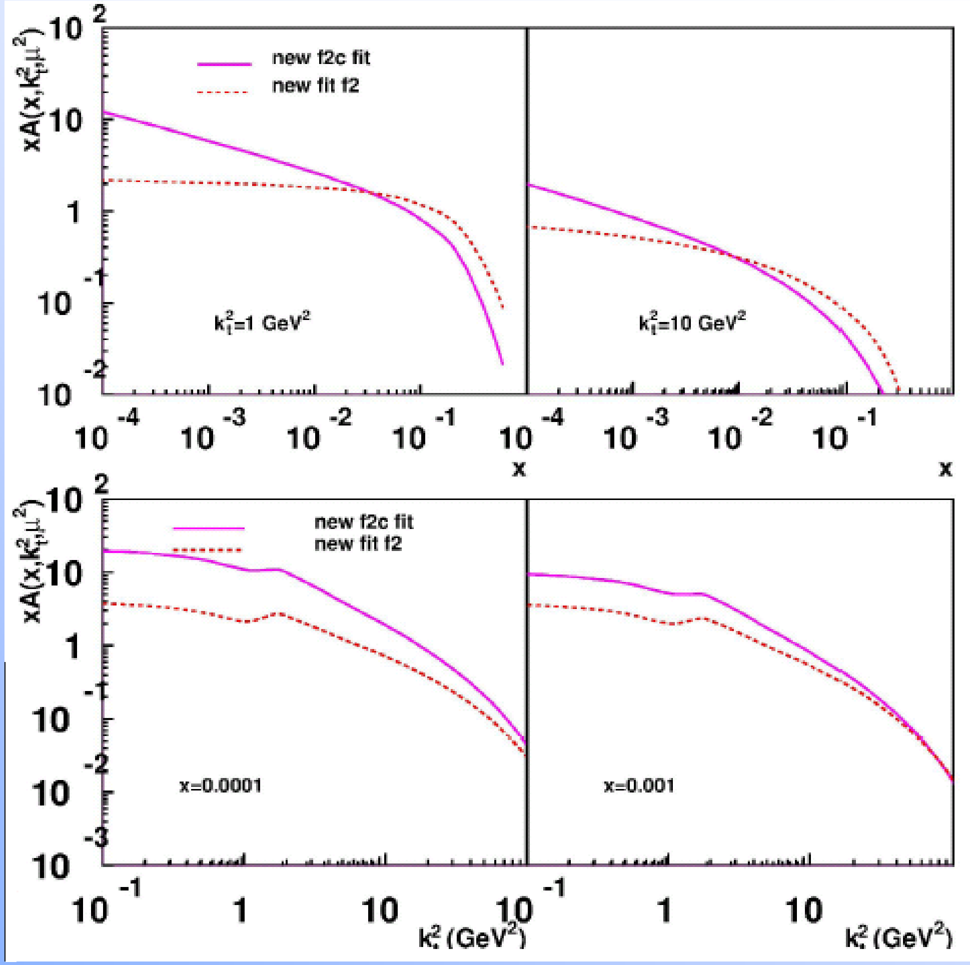
⇒ Gluon universality!

# Gluon density from fits to $F^c_2$

*Hannes Jung & Axel Cholewa , ICHEP06*

- CCFM fits to $F_2$ and $F^c_2$ give order of magnitude difference in $g(x)$ at low $k_T$



# Gluon density from fits to $F^c_2$

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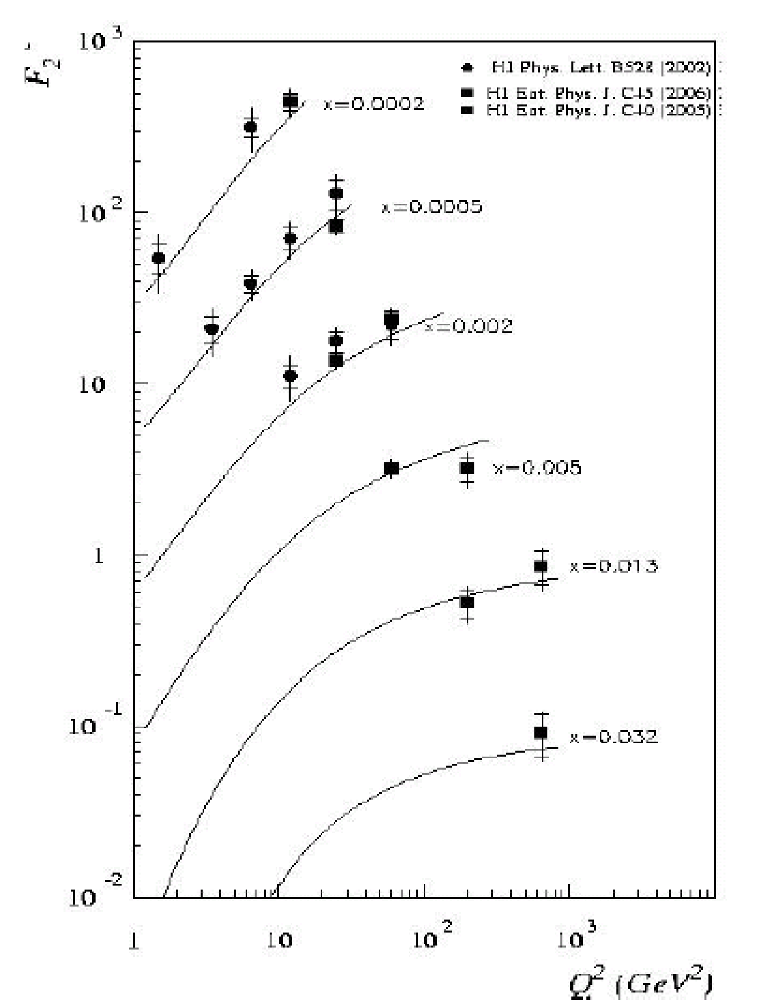
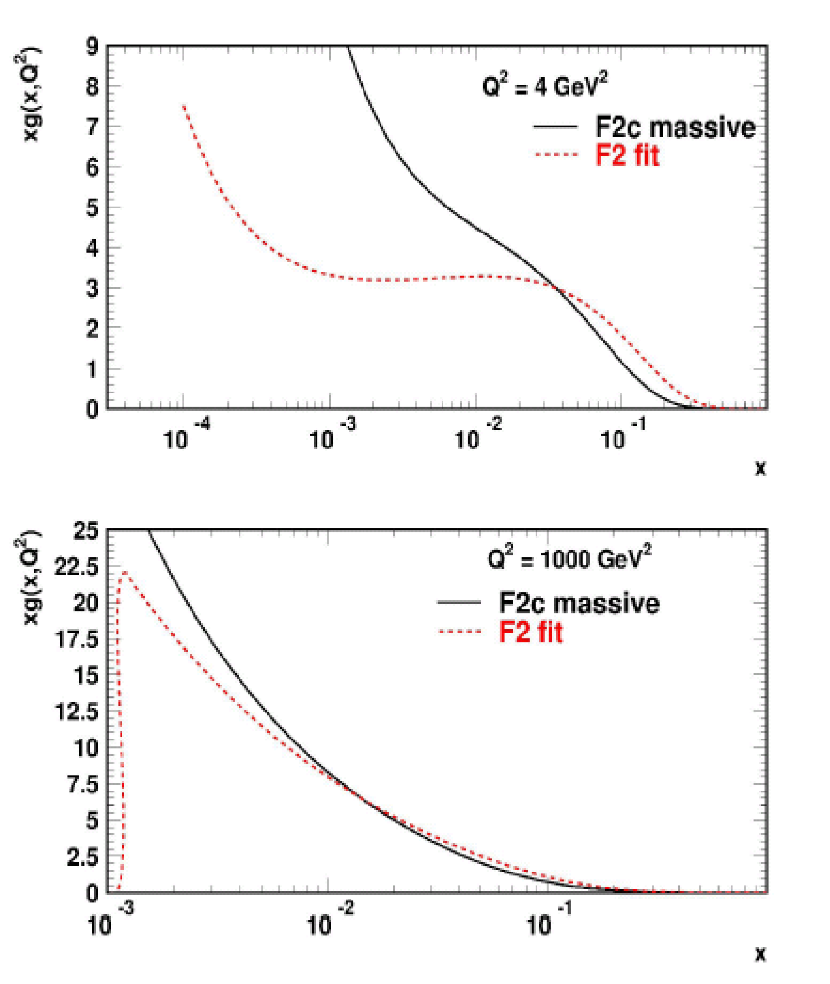
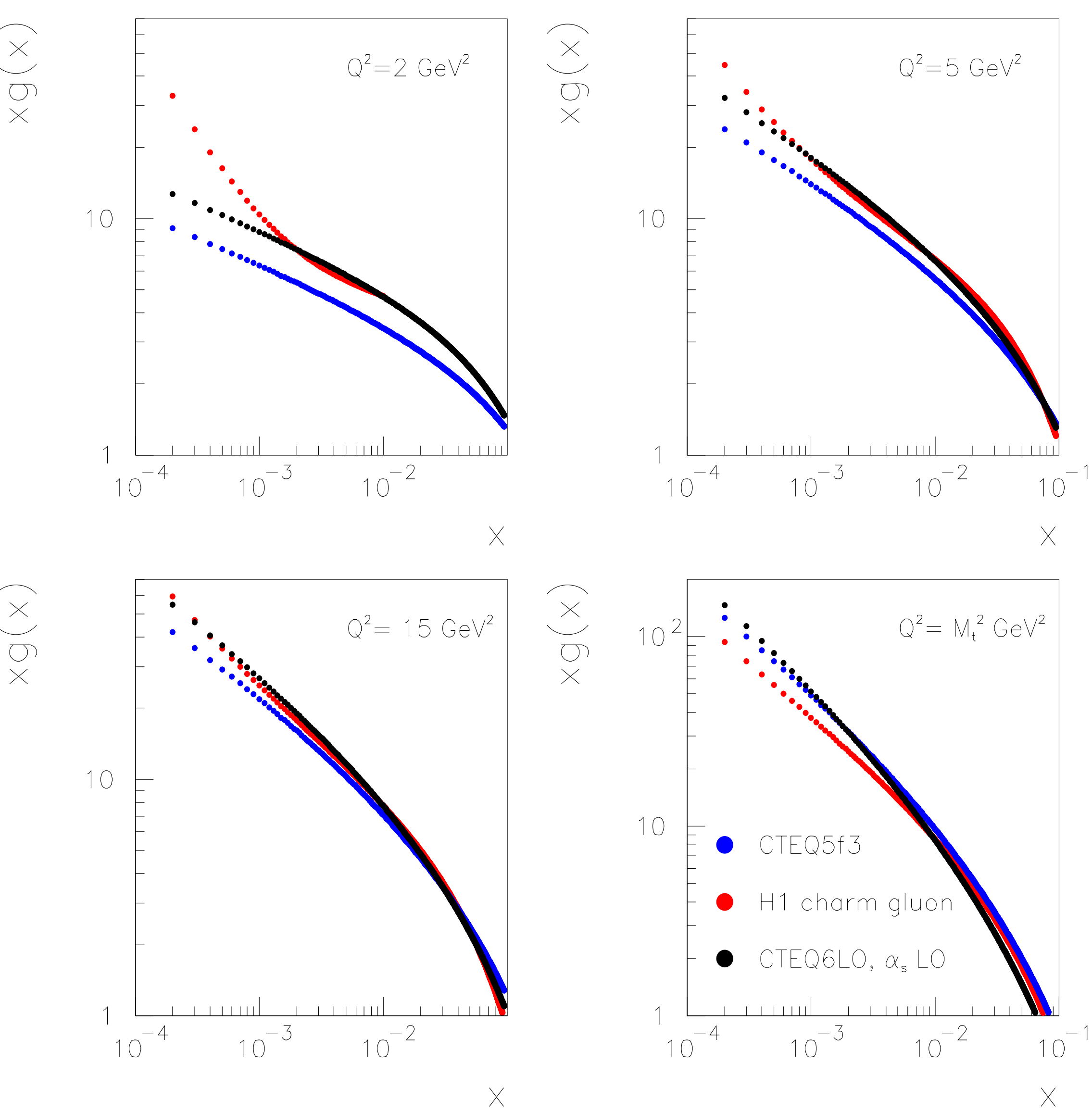
- CCFM fits to $F_2$ and $F^c_2$ give order of magnitude difference in $g(x)$ at low $k_T$
- DGLAP fits to $F^c_2$ : steeper gluon at low x compared to inclusive $F_2$

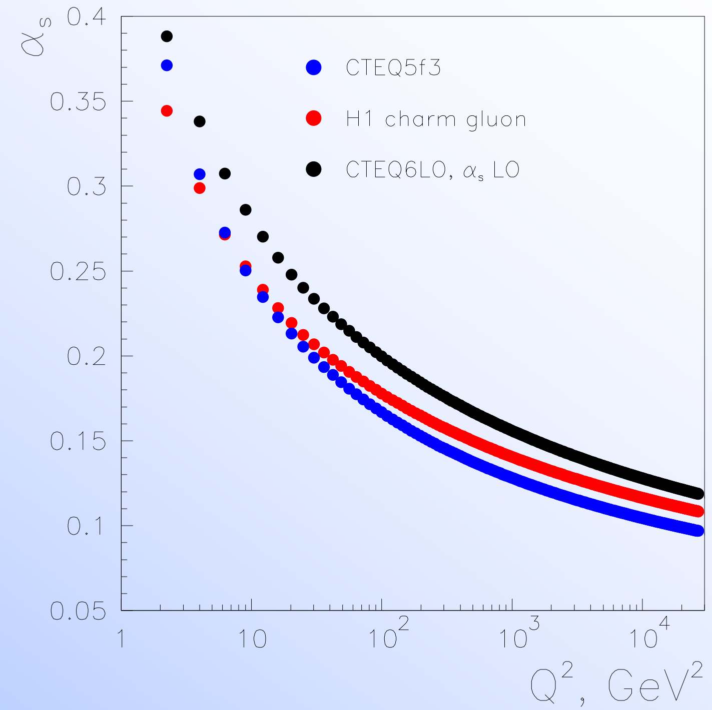


# Comparison with other gluon densities

## CTEQ5F3 and CTEQ6LO vs. H1 "charm gluon"

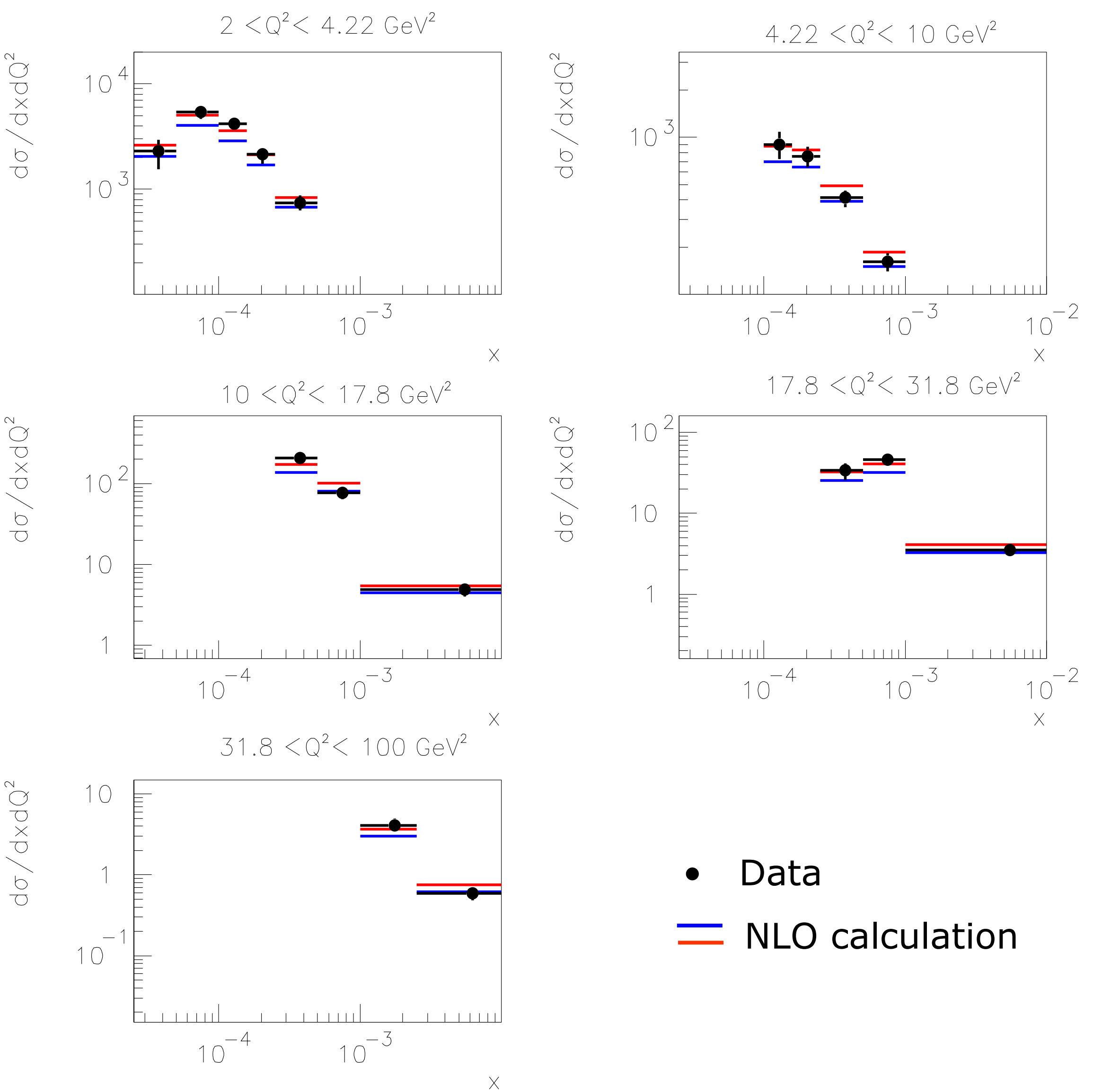



➢ H1 "charm gluon" steeper at low $Q^2$, low x.

# NLO cross section vs. H1 $D^*$ DIS data

- Gluon distributions used as input to the NLO cross-section calculation




- Data: H1 publication

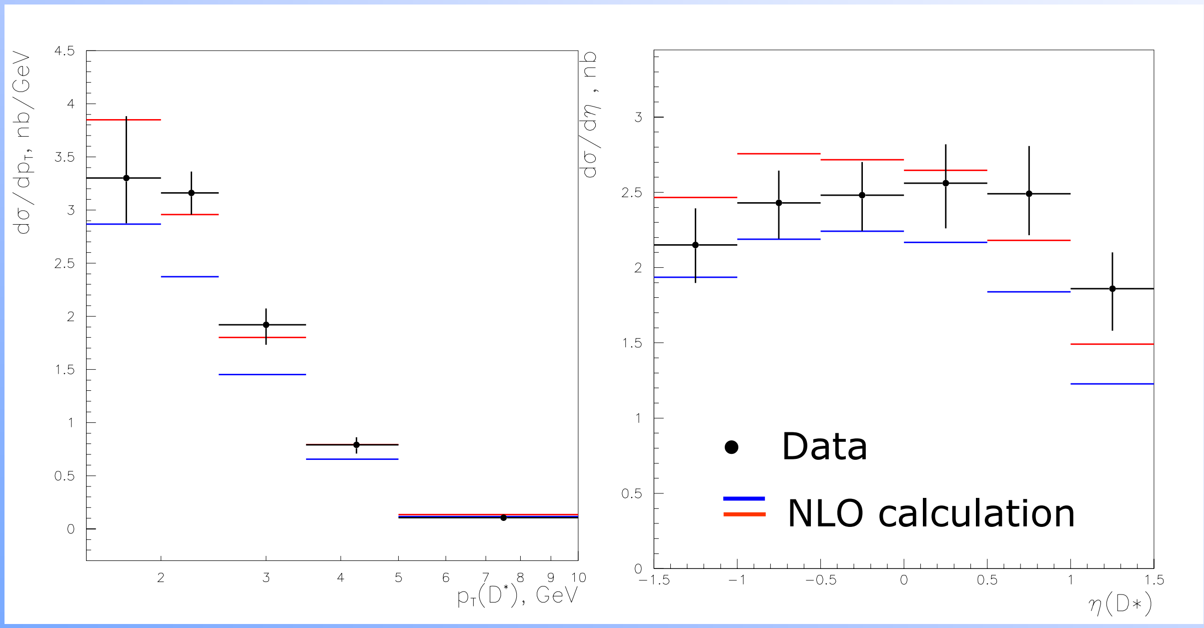
  NLO predictions with $m_c$=1.5 , $\mu^2 = Q^2 + 4m_c^2$

- PDFs:
  - gluon from H1 fit to $F^c_2$
  - CTEQ5F3

➢ NLO prediction with "gluon from charm" gives better results at low $Q^2$ and low x.

# NLO cross section using gluon from $F^c_2$ vs. H1 $D^*$ DIS data

$d\sigma(e\,p \rightarrow D^*\,X)/dkin$



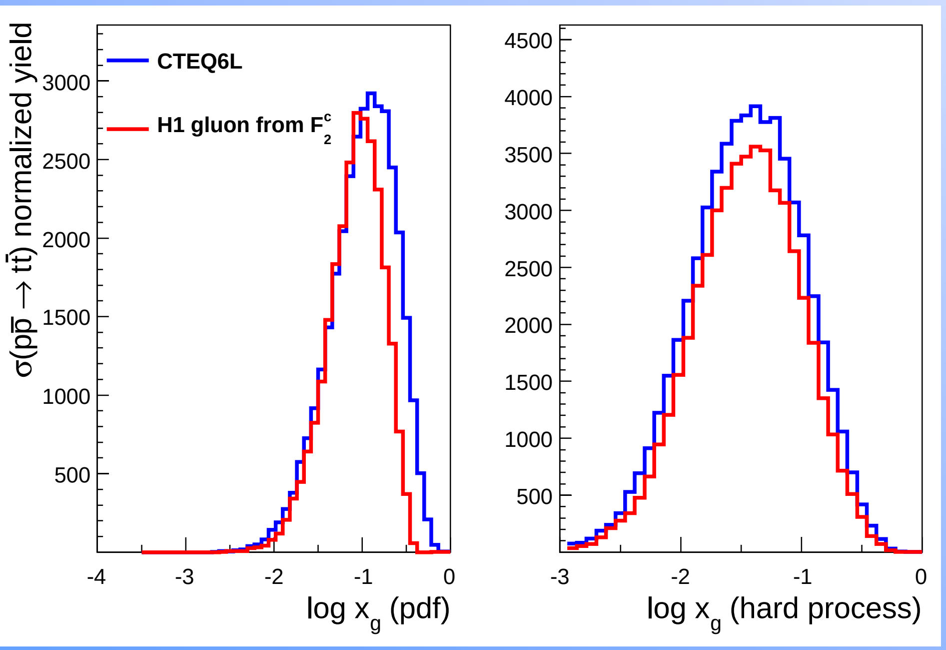

- PDFs:
  - gluon from H1 fit to $F^c_2$
  - CTEQ5F3
- quite different $p_T(D^*)$ slope

➢ Data: H1 publication NLO predictions with

$m_c$=1.5 , $\mu^2 = Q^2 + 4m_c^2$

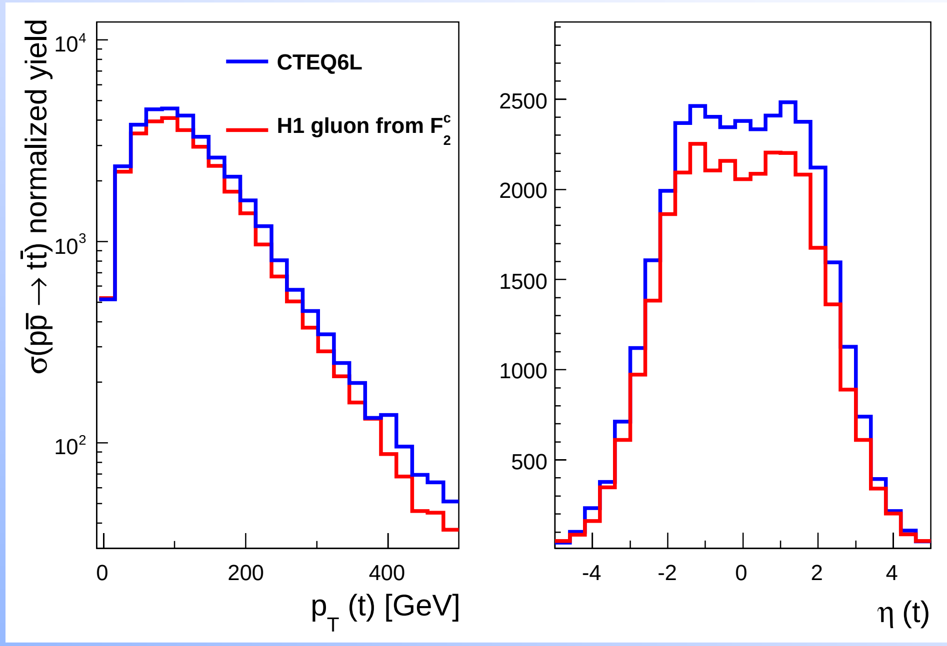
# Curiosity: Top production at the LHC

- Simulated 30000 $t\bar{t}$ events with CTEQ6LO and the gluon from H1 fit to $F^c_2$
  - PYTHIA 6.4 using LHAPDF version 5.2.2
  - Difference in predicted $\sigma_{tot}$ ($pp \rightarrow t\bar{t}$) is 14%
  - The average $x_g$-value is smaller for H1 $g(x)$
  - $p_T$ (Top) spectrum slopes slightly different.




Before ISR

After ISR



# Conclusion

- Top-quark production cross-section (generator level) with parton densities was studied:

  - 14% different x-section
  - No big effect on $p_T$ (Top) slope at LHC
  - Uncertainties of the gluon distribution are not taken into account
  - x-sections with unintegrated gluon should be studied with CASCADE
    - Not yet standard MC generator at CMSSW!

- Work to include the HERA final state cross-section into the PDFs in progress..