Gluon distributions at very low x and the BFKL signature at LHCb

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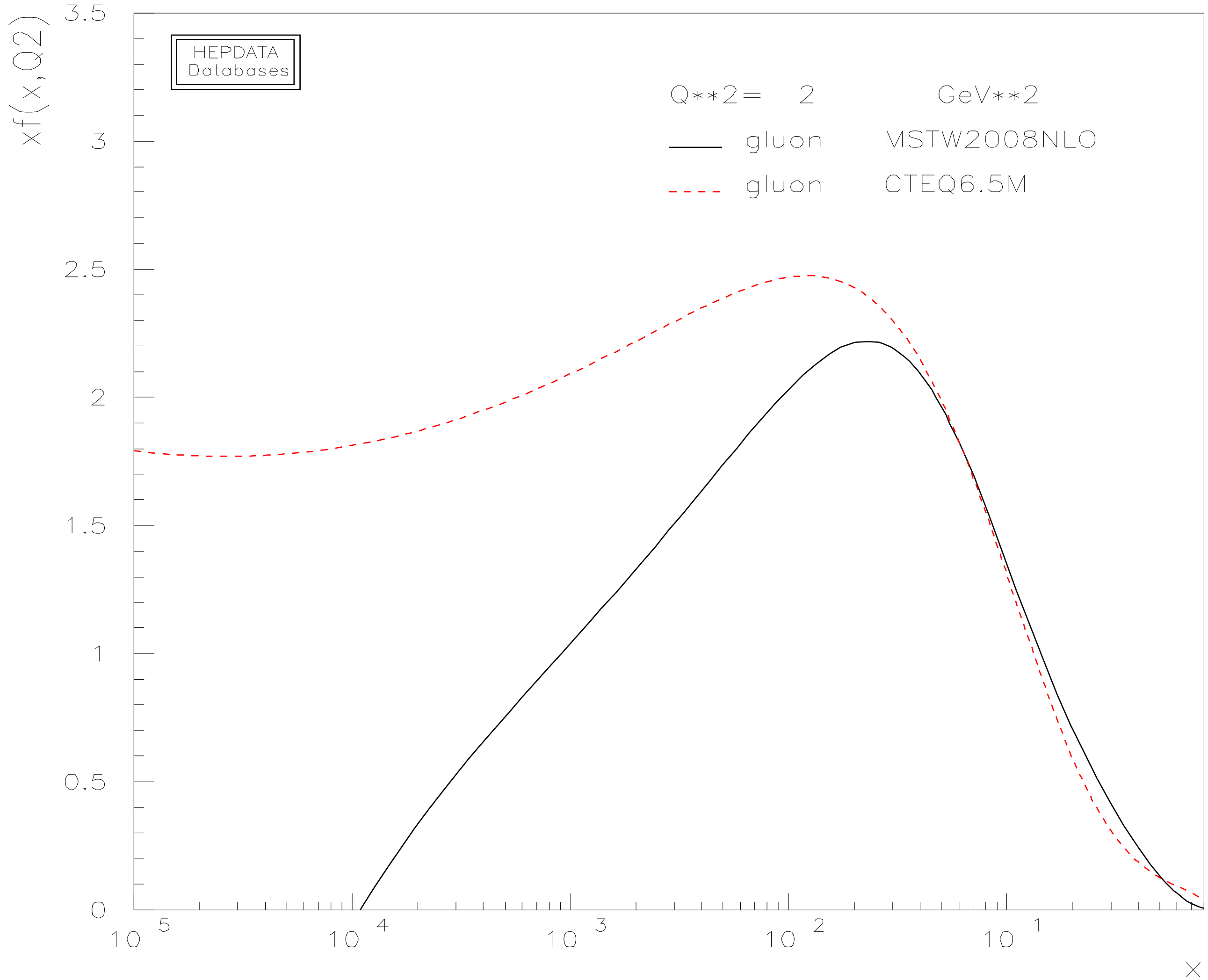
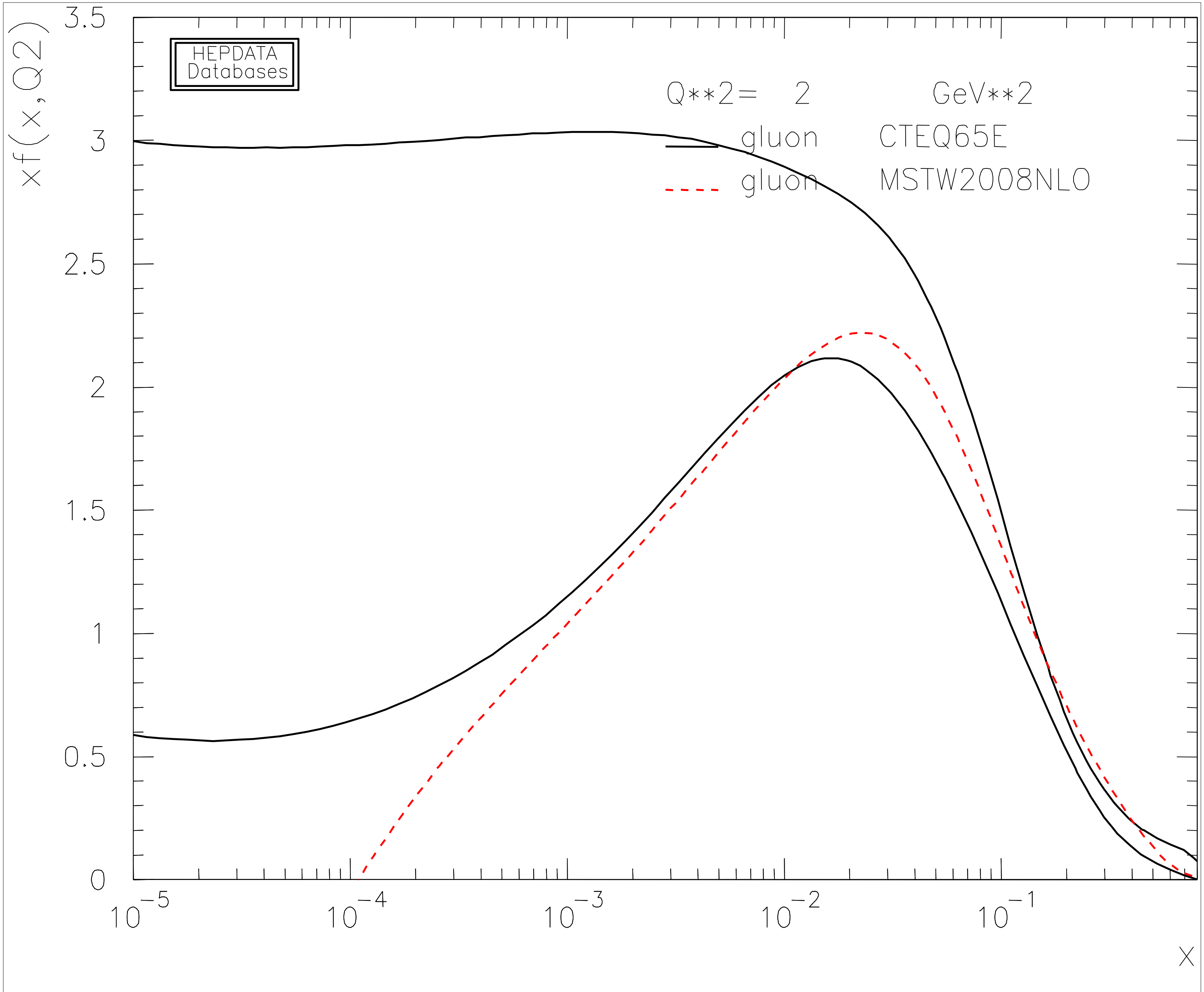
1. Open beauty $\sigma(b\bar{b})$ – way to measure $g(x, Q^2)$ at low x

2. BFKL predicts **flat** q_T distribution $\frac{d\sigma}{dq_T^2} \propto 1/p_T^3$

1. Gluons at low x and low Q^2 are not well constrained/known





HEPDATA
Databases
Q**2= 2 GeV**2
gluon CTEQ65E
gluon MSTW2008NLO
xf(x,Q2)
X
3.5
3
2.5
2
1.5
1
0.5
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}

1. Gluons at low x and low Q^2 are not well constrained/known

a) at low x - the data from DIS (HERA) only
b) DIS does not 'measure' $g(x, Q^2)$ directly

DGLAP accuracy is *not* justified at low x
(especially for derivative $\partial F_2/\partial Q^2$)

i) BFKL-like $\Sigma_n C_n(\alpha_s \ln(1/x))^n$ contributions
ii) absorptive corrections -
- (a) next twist $\sim 1/Q^2$ suppressed, but
- (b) $x^{-\lambda}$ **enhanced** $(\lambda \sim 0.3)$

(a) and (b) compensate each other at $x \sim 10^{-4}$ and $Q^2 \sim 10$ GeV^2

Open $b\bar{b}$ at LHCb - direct info about $g(x,Q^2)$

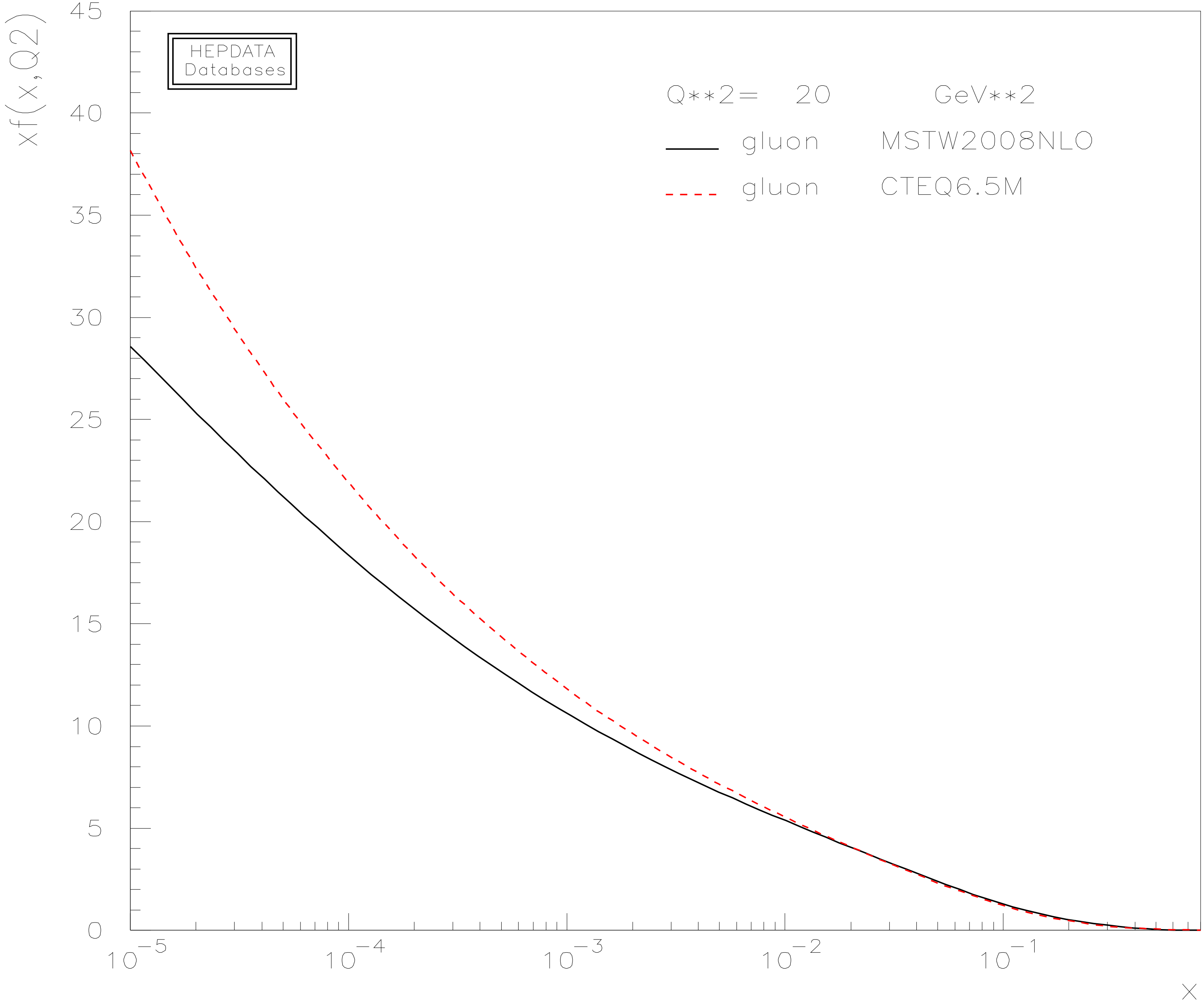
at $\eta \sim 4-5$ we can probe the scale $Q^2 \sim m_b^2 \sim 20$ GeV^2
and

$$x_{1,2} = M_{bb}/\sqrt{s}\exp(\pm\eta) \sim 10^{-4} \ - \ 10^{-5}$$

$$\sigma(b\bar{b}) = \int dx_1 dx_2 g(x_1,Q^2) d\hat{\sigma}(gg \to b\bar{b}) g(x_2,Q^2) \sim 20\mu\text{b}$$

for $Q^2 \sim 20$ GeV^2, $x_1 \sim 10^{-4}$ and $x_2 \sim 0.01$ (($g(x_2,Q^2)$ is known).

NLO corrections are known.


HEPDATA
Databases
Q**2= 20 GeV**2
gluon MSTW2008NLO
gluon CTEQ6.5M
xf(x,Q2)
45
40
35
30
25
20
15
10
5
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
X

A lower scale $Q^2 \sim 2$ GeV^2 and $x \sim 10^{-5}$
can be studied via open charm, $\sigma(gg \longrightarrow c\bar{c})$, production.

If possible – to measure $gg \longrightarrow \chi_c$
$\chi_c \longrightarrow KK$ or $\chi_c \longrightarrow J/\psi + \gamma$
(but the background=?)

(Br($\chi_c \longrightarrow K^+K^-$) = 0.6%, Br($\chi_c \longrightarrow K_s^0 K_s^0$) = 0.3%)

$$Br \cdot \sigma(\chi_c) \sim 5 \ - \ 10\text{nb}$$
.

while the expected KK background under the χ_c peak is of the order of 10μb.

(may be better – $\chi_c \longrightarrow f_0(980) f_0(980)$, Br=0.07%
or $\chi_c \longrightarrow \phi\phi$, Br=0.09% .

2. **BFKL versas DGLAP**

Double Logs $\Sigma_n C_n(\alpha_s \ln(1/x) \ln Q^2)^n$ are the same

.

DGLAP	BFKL
$\Sigma_n C_n(x)(\alpha_s \ln Q^2)^n$	$\Sigma_n f_n(q_T^2)(\alpha_s \ln(1/x))^n$
.	.
leading twist	**all** twists
.	.
$k_{T,n+1} >> k_{T,n}$	no k_T ordering (diffusion in $\ln k_T$)
.	.
$\gamma \sim \alpha_s << 1$	$\gamma \to 1/2$

$g(x, Q^2) \propto (Q^2)^\gamma$

Recent LHC data:

$dN/d\eta$ grows with $\sqrt{s}$ faster
while $< p_t >$ is smaller

than that predicted by DGLAP based MC

indicate an important role of the contributions

not ordered in k_t ,

that is in favour of BFKL.

$$\frac{Ed\sigma}{dydp_T^2} \sim g(x_1 < p_T^2)\frac{d\hat{\sigma}}{dp_T^2}g(x_2, p_T^2) \sim \frac{(p_T^2)^{\gamma_1+\gamma_2}}{p_T^4}$$

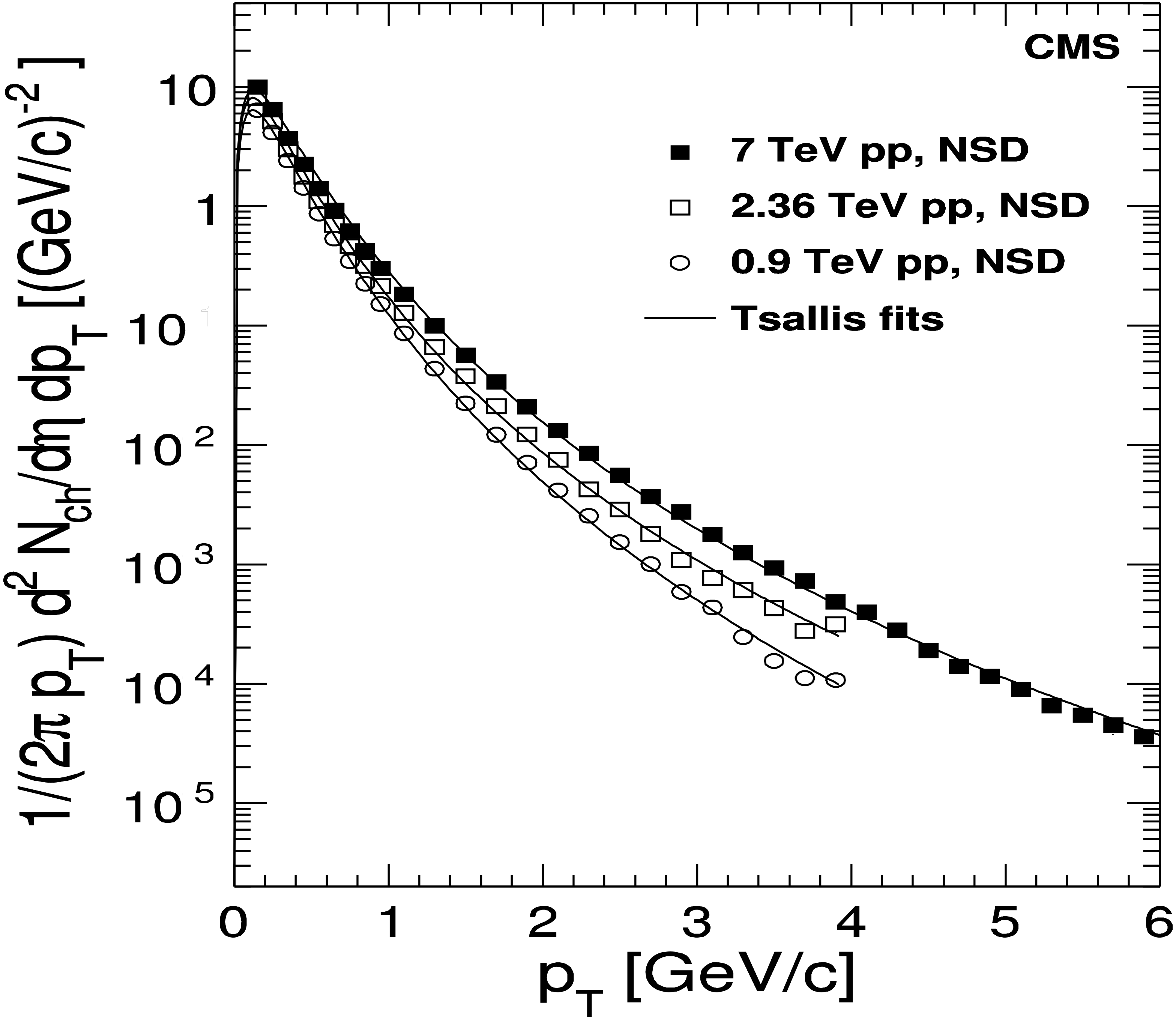
($g(x, p_T^2) \propto (p_T^2)^\gamma$)

BFKL predicts anomalous dimension $\gamma \rightarrow 1/2$ for $x << 1$.

CMS observe $d\sigma/dp_t^2 \sim 1/p_T^6$
(not $1/p_T^2$ as it should be for $\gamma_1 = \gamma_2 = 1/2$)

Explanations:
a) hadronization / jet fragmentation
b) "thermalization" of secondaries

LHCb can measure jets with $p_T > 30$ GeV, still low x (pure pQCD)
$\sigma \sim 1\mu$b


CMS
7 TeV pp, NSD
2.36 TeV pp, NSD
0.9 TeV pp, NSD
Tsallis fits
1/(2π p_T) d^2 N_ch/dη dp_T [(GeV/c)^-2]
p_T [GeV/c]
10
1
10
10 2
10 3
10 4
10 5
0
1
2
3
4
5
6

p_T distribution of B-mesons very **close** to 'parton' (b-quark)

due to strong *leading* effect $\quad z_B > 0.8)$

and low $\sigma(b)$ for final state interactions.

$(d\sigma(B)/dp_T^2 \sim 0.1\mu\text{b}$ for $p_T > 10$ GeV)

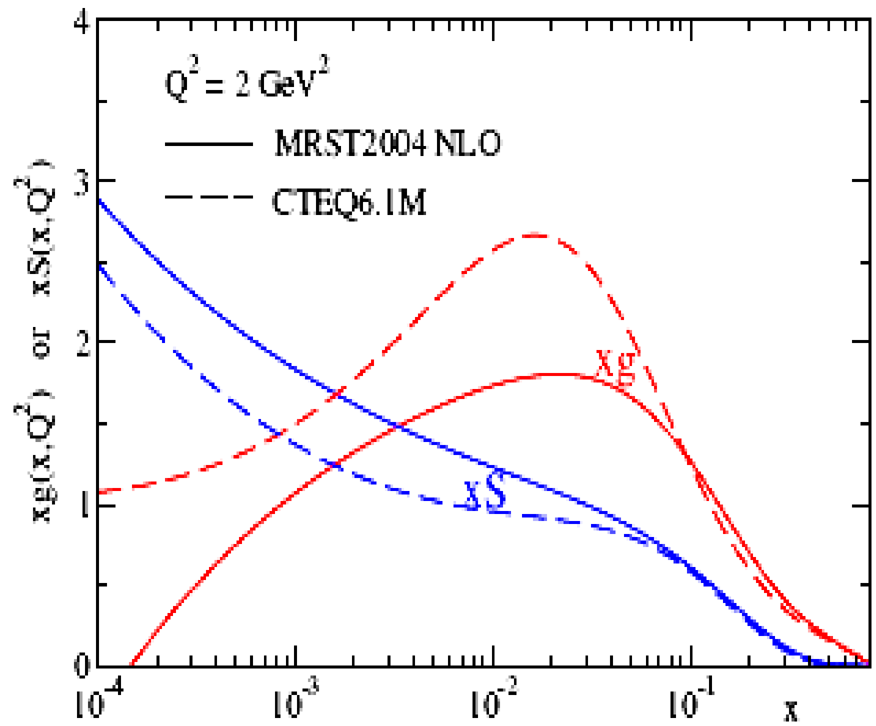
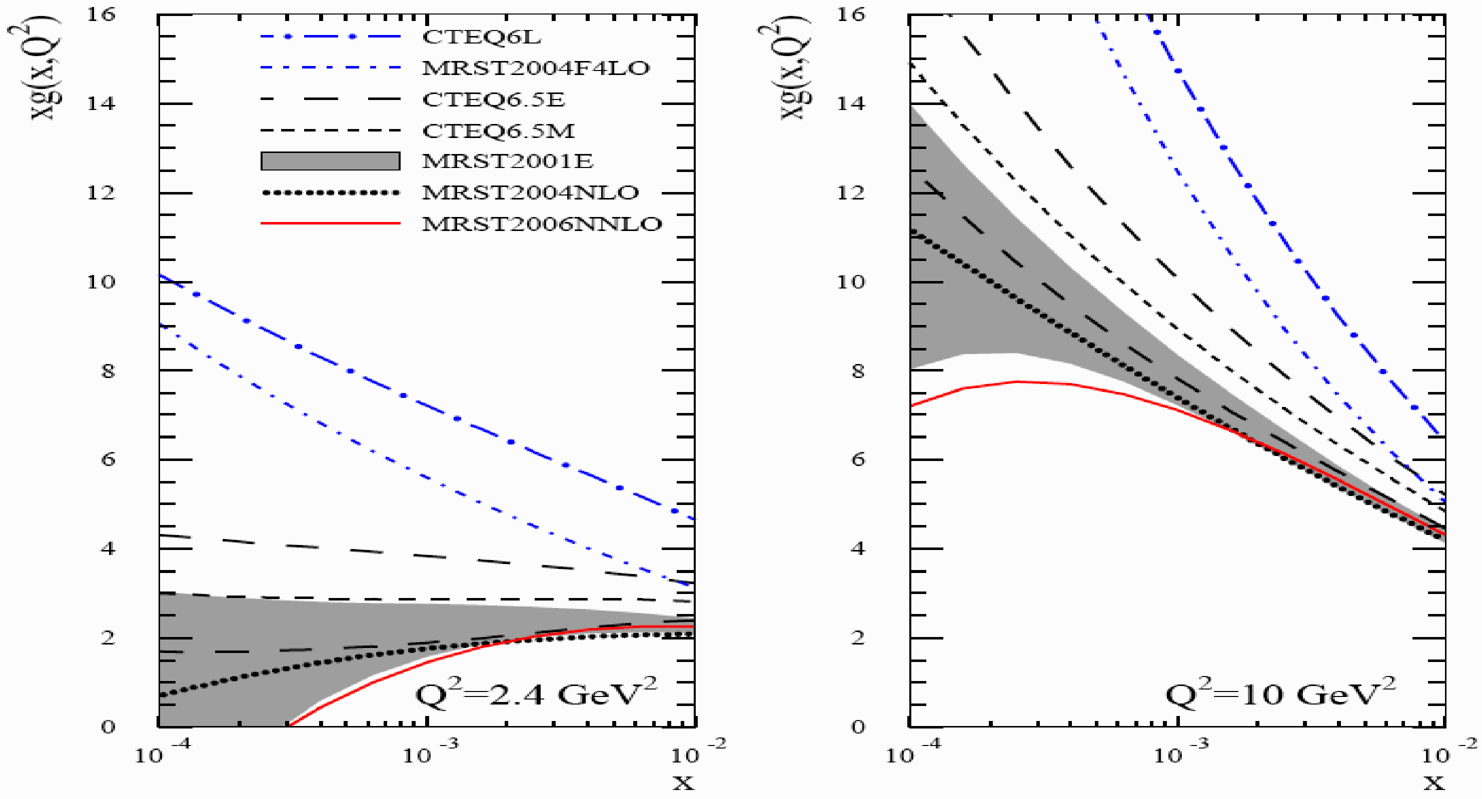


Fig. 2: The behaviour of the gluon and sea quark distributions at $Q^2 = 2$ GeV^2 found in the CTEQ6.1M [17] and MRST2004 NLO [18] global analyses. The valence-like behaviour of the gluon is evident.



re 1: Comparison of recent global fits of the gluon distribution at small x at leading , next-to-leading (NLO) and next-to-next-to leading (NNLO) order, for the two scales = 2.4 (left) and 10 GeV^2 (right panel). LO gluons (dash dot) compared are CTEQ6L [1] and T2004F4LO [2]. The two (long) dashed lines indicate the error estimate of the CTEQ6.5 [3] n and the shaded band is the error band for the MRST2001 [4] global gluon. Central values he NLO global fits are from CTEQ6.5M (short dashed) and MRST2004NLO [5] (dotted). solid line represents MRST2006NNLO [6].

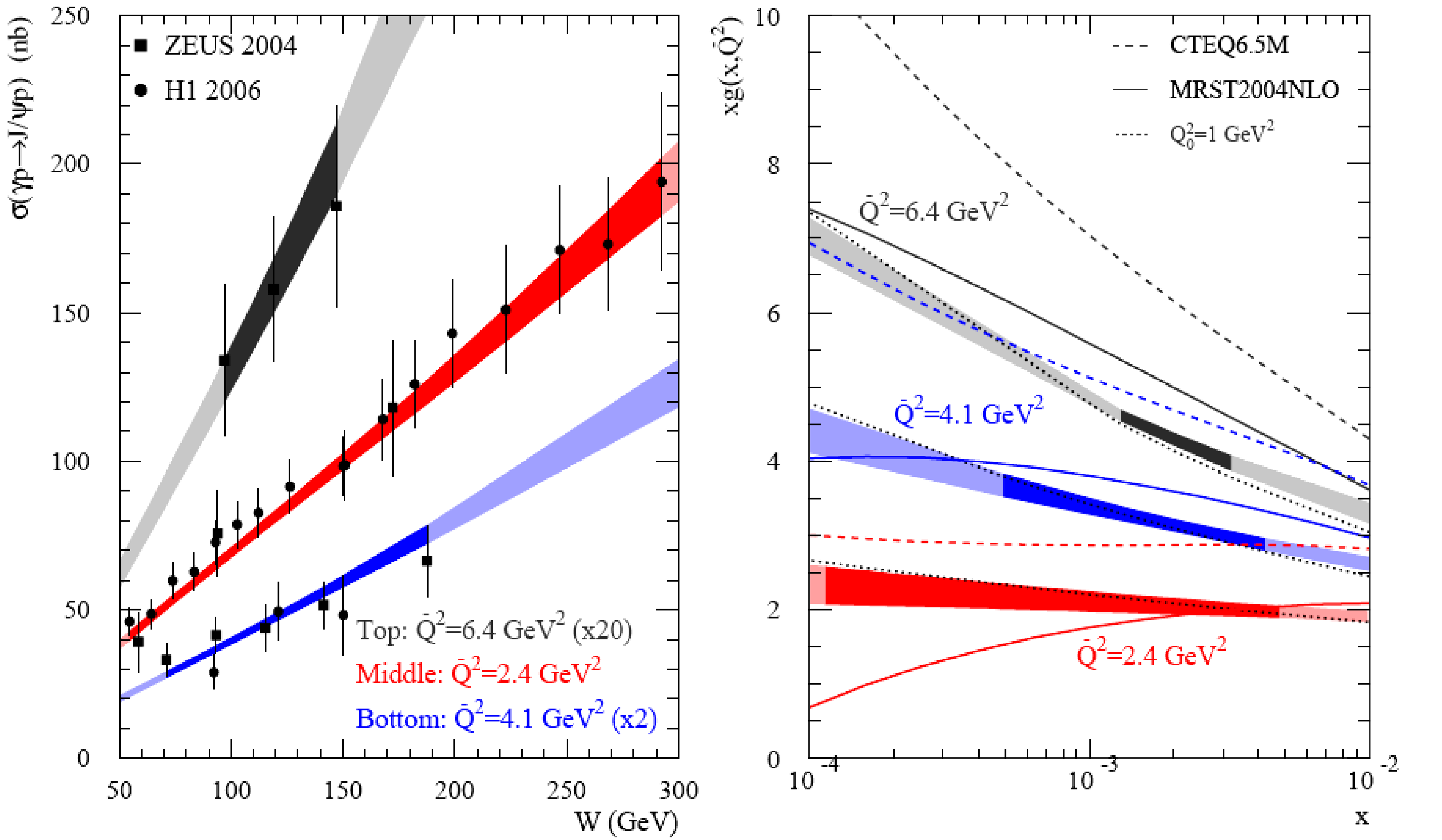
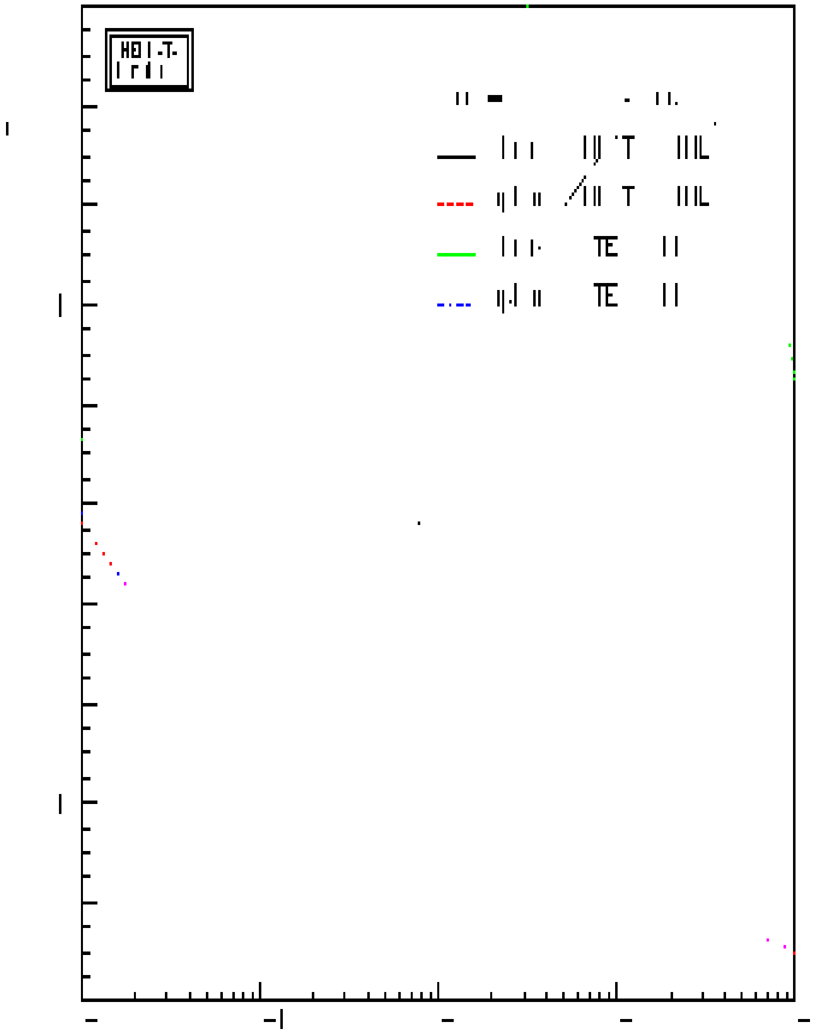
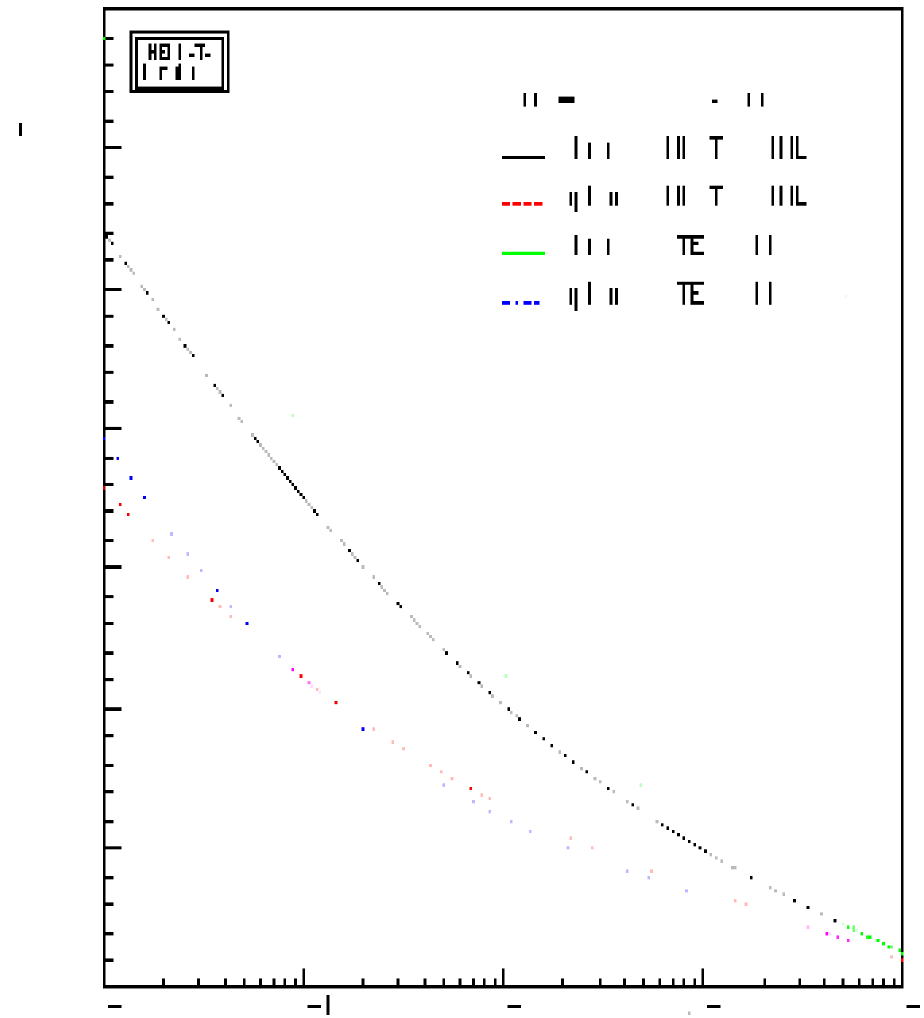
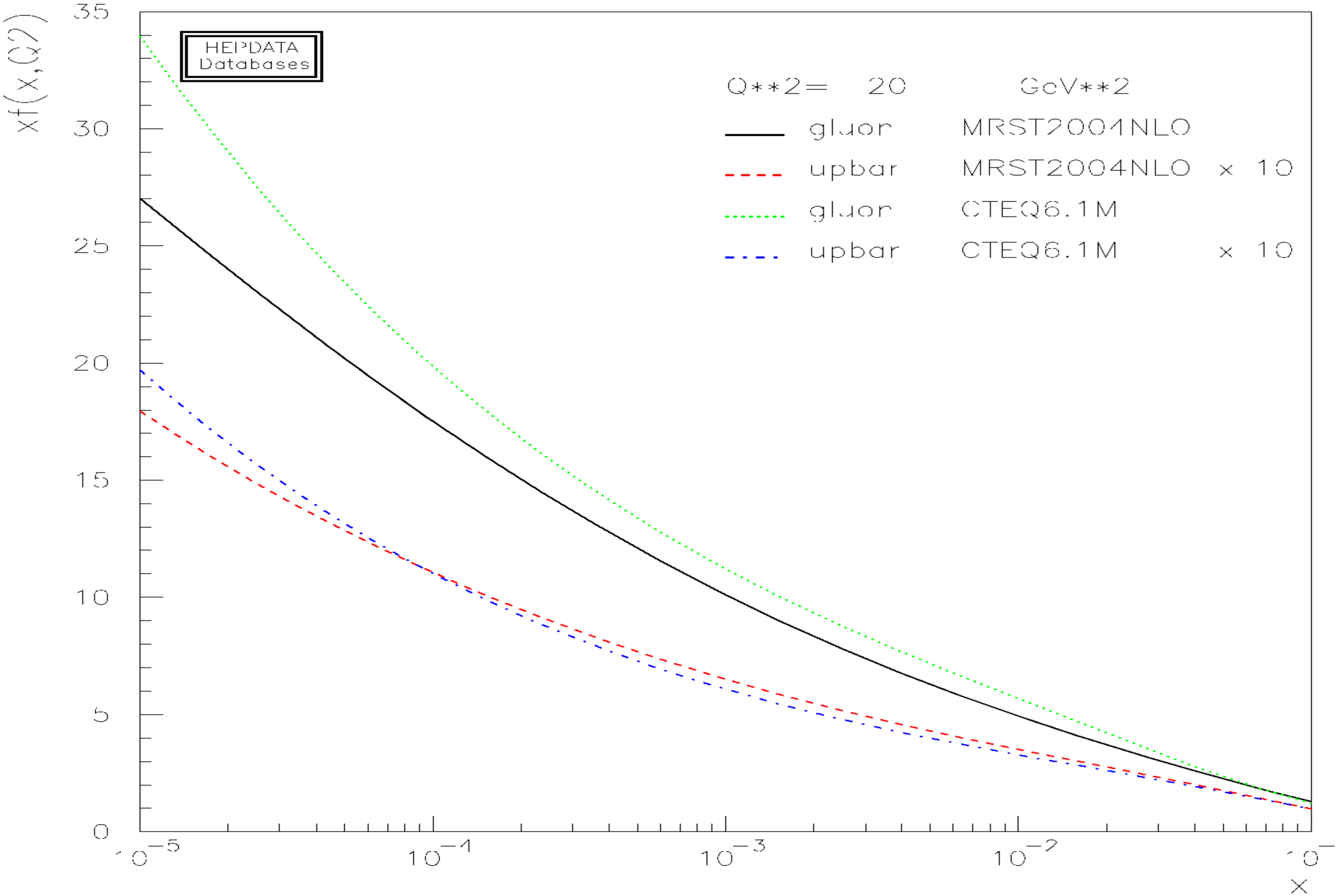


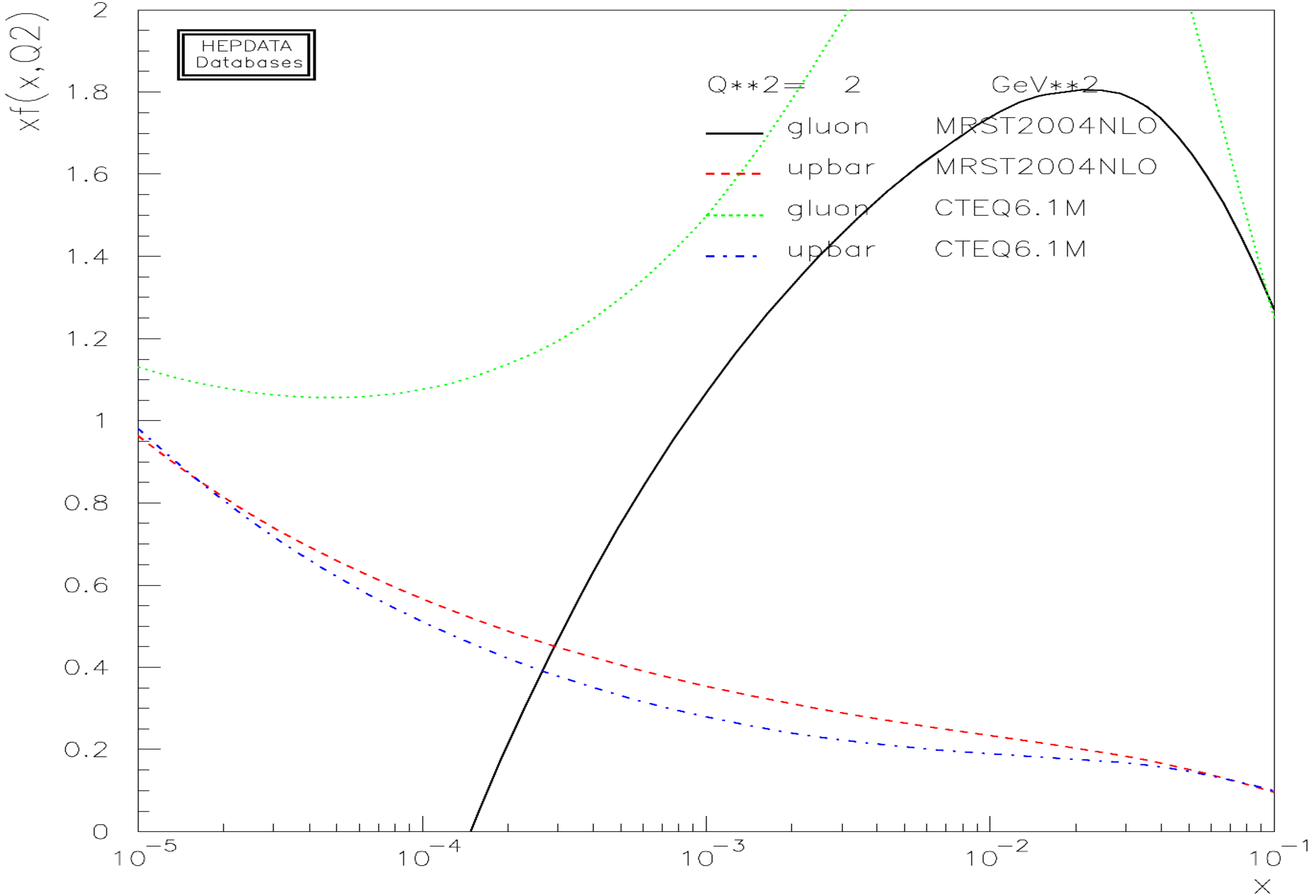
Figure 4: As Fig. 3, but for the next-to-leading order fit and comparing to NLO global fits from CTEQ6.5M [3] and MRST2004 [5].



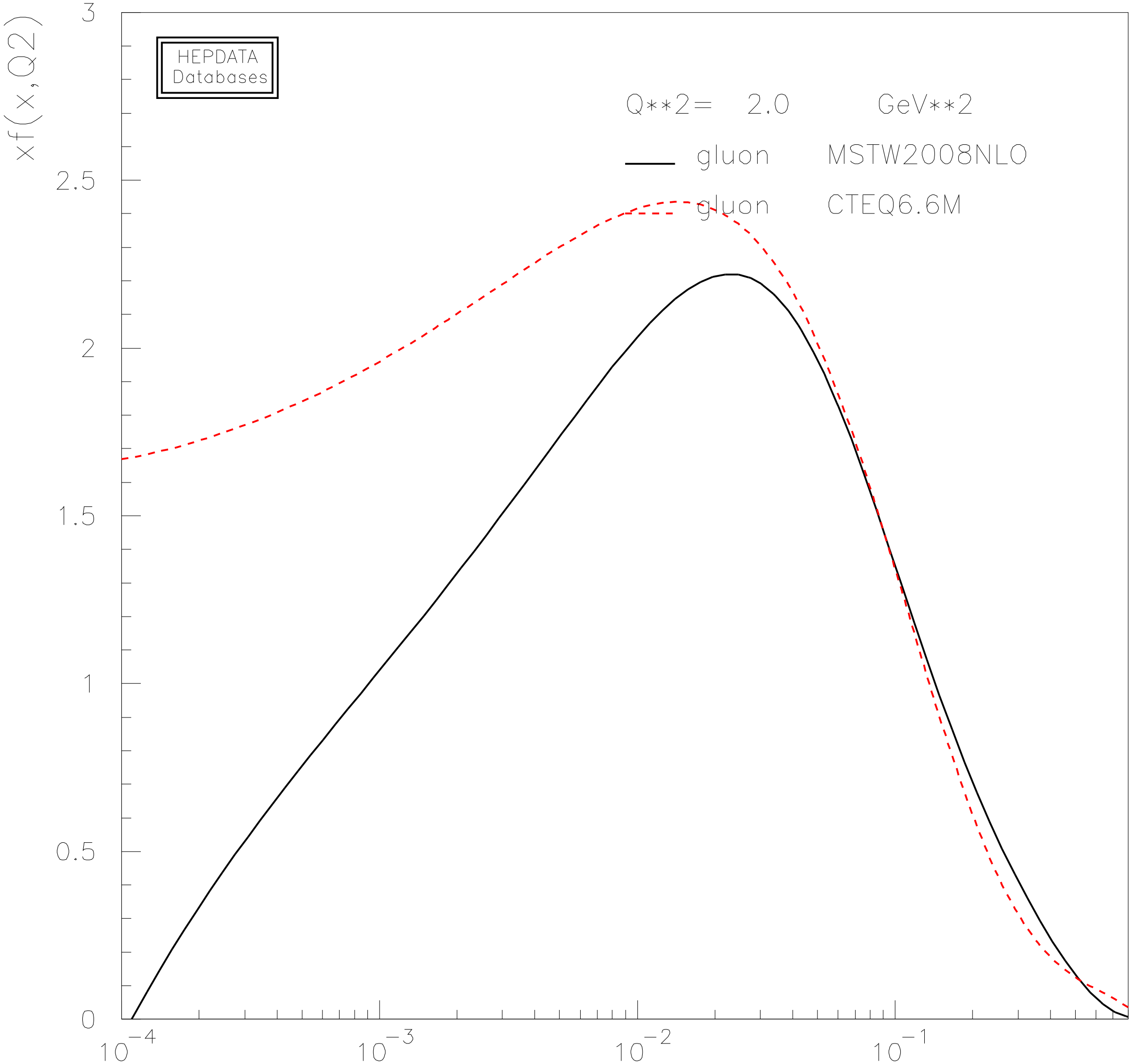




HEPDATA
Databases
Q**2= 20 GeV**2
gluon MRST2004NLO
upbar MRST2004NLO x 10
gluon CTEQ6.1M
upbar CTEQ6.1M x 10
xf(x,Q2)
x



HEPDATA
Databases
Q**2= 2 GeV**2
gluon MRST2004NLO
upbar MRST2004NLO
gluon CTEQ6.1M
upbar CTEQ6.1M
xf(x,Q2)
x
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}



HEPDATA
Databases
Q**2= 2.0 GeV**2
gluon MSTW2008NLO
gluon CTEQ6.6M
xf(x,Q2)
3
2.5
2
1.5
1
0.5
0
10^{-4}
10^{-3}
10^{-2}
10^{-1}