Parton evolution with α_s at small k_T

DGLAP evolution – solution with parton branching method

- $$f(x,\mu^2) = f(x,\mu_0^2)\Delta_s(\mu^2) + \int^{z_M} \frac{dz}{z} \int \frac{d\mu'^2}{\mu'^2} \cdot \frac{\Delta_s(\mu^2)}{\Delta_s(\mu'^2)} P^{(R)}(z) f\left(\frac{x}{z}, \mu'^2\right)$$

$$f_0(x,\mu^2) \quad = \quad f(x,\mu_0^2)\Delta(\mu^2)$$

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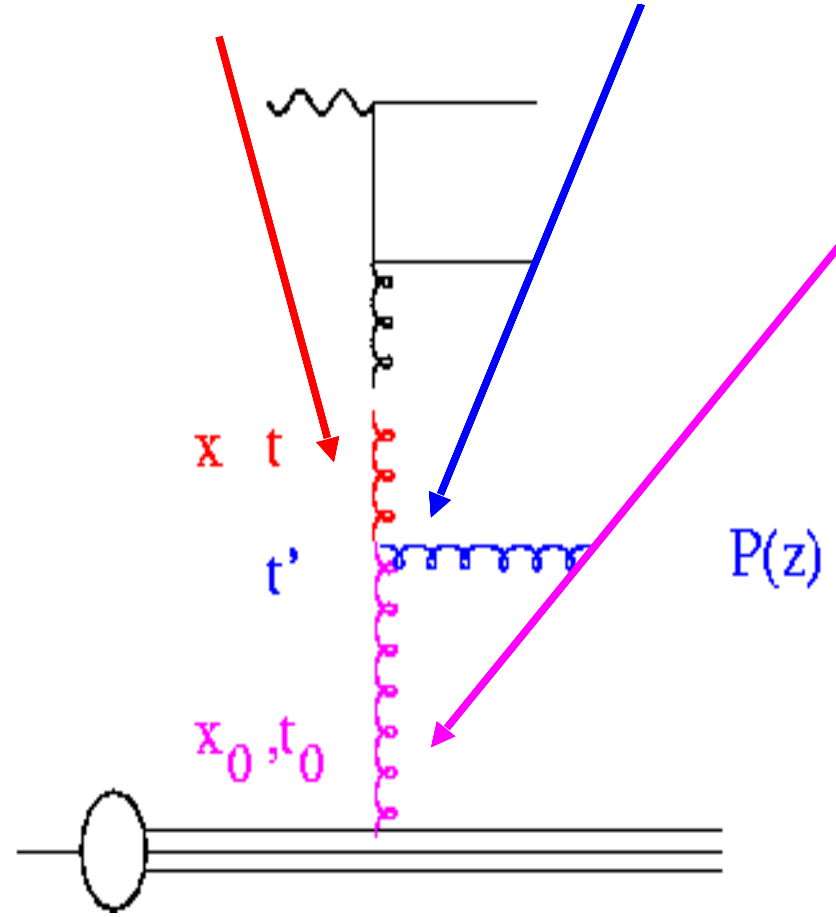
from μ' to μ w/o branching

branching at μ'

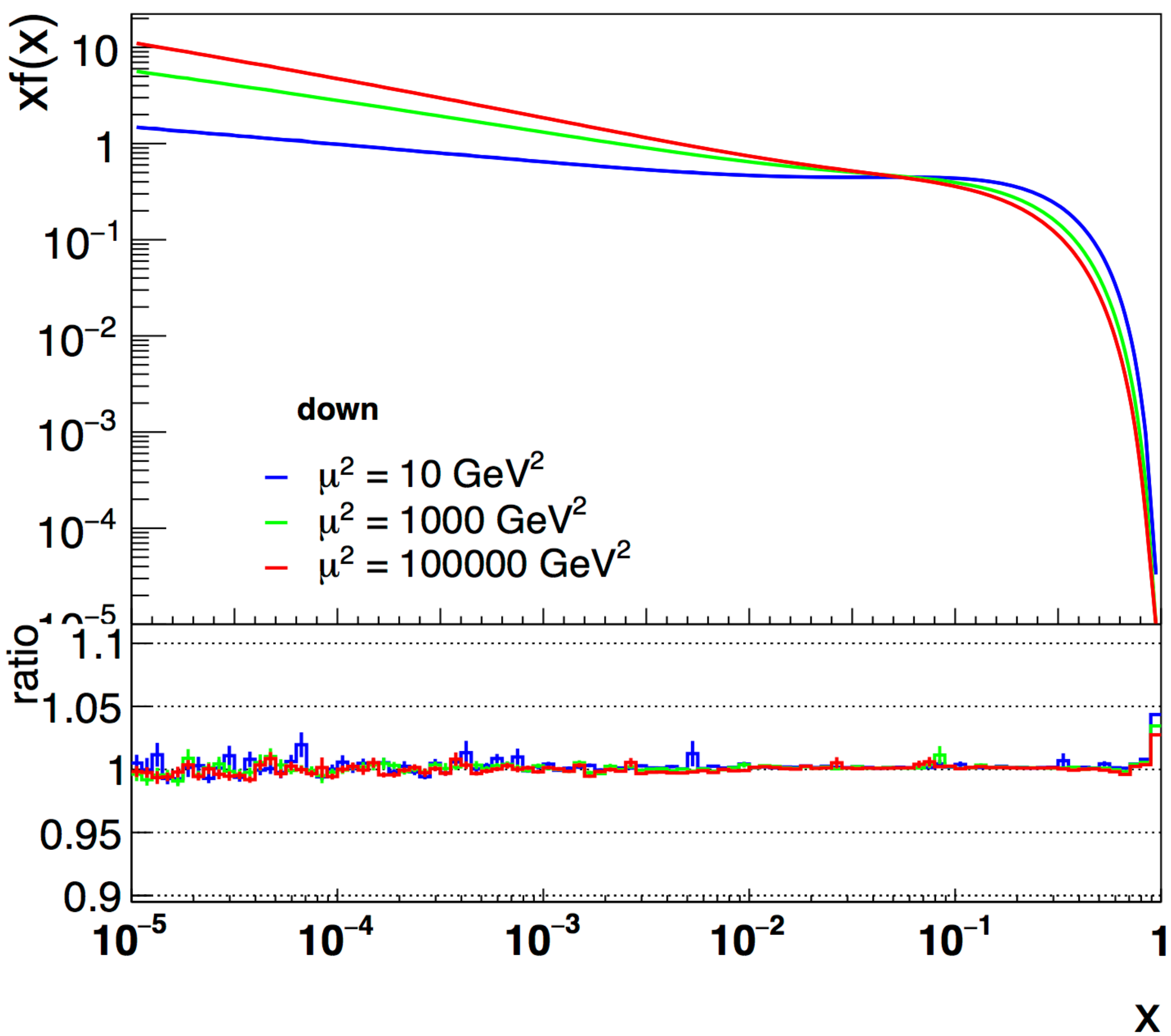
from μ to μ' w/o branching

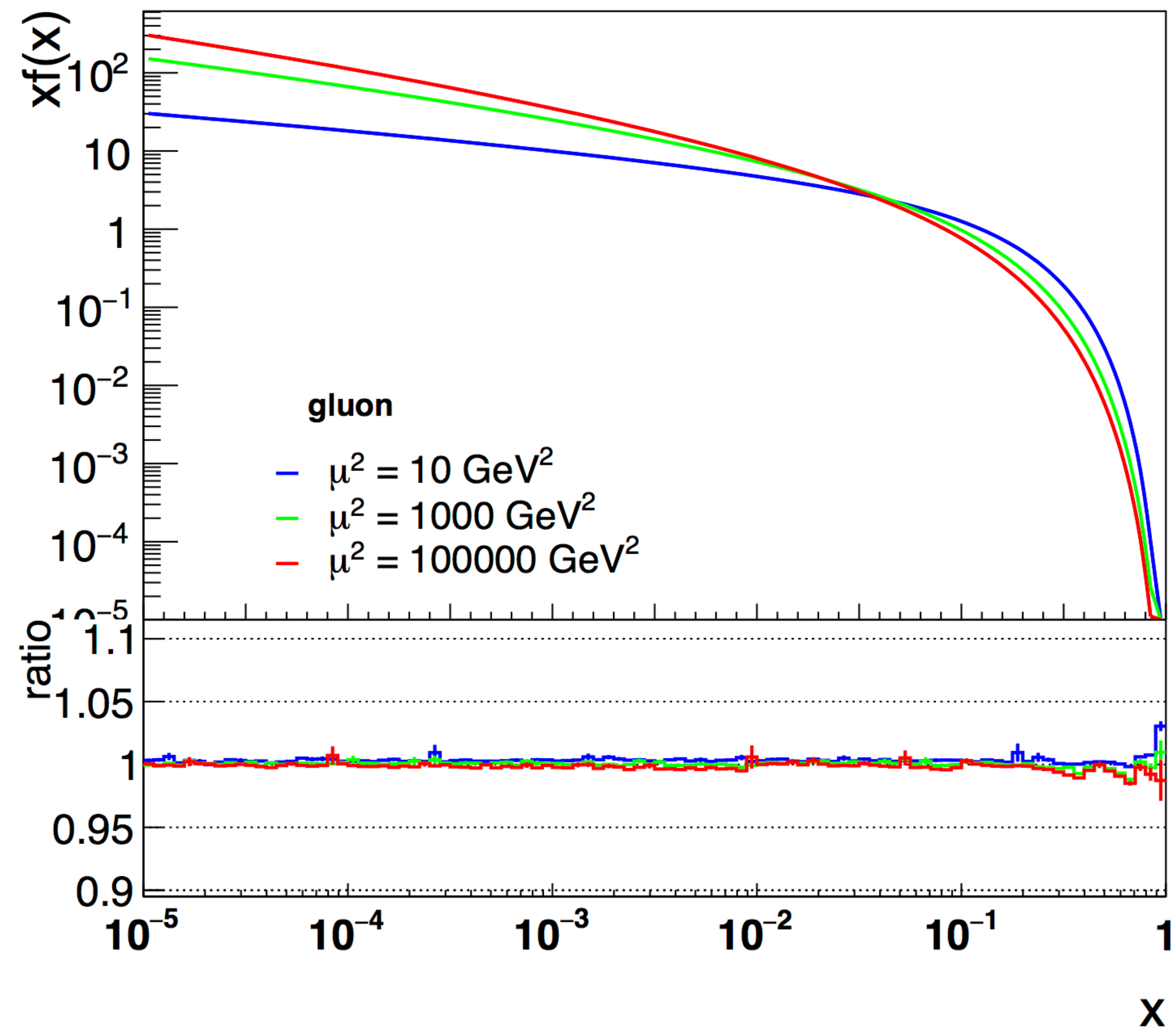
$$f_0(x,\mu^2) = f(x,\mu_0^2)\Delta(\mu^2)$$

$$f_1(x,\mu^2) = f(x,\mu_0^2)\Delta(\mu^2) + \int_{\mu_0^2}^{\mu^2} \frac{d\mu'^2}{\mu'^2} \frac{\Delta(\mu^2)}{\Delta(\mu'^2)} \int^{z_M} \frac{dz}{z} P^{(R)}(z) f(x/z,\mu_0^2)\Delta(\mu'^2)$$



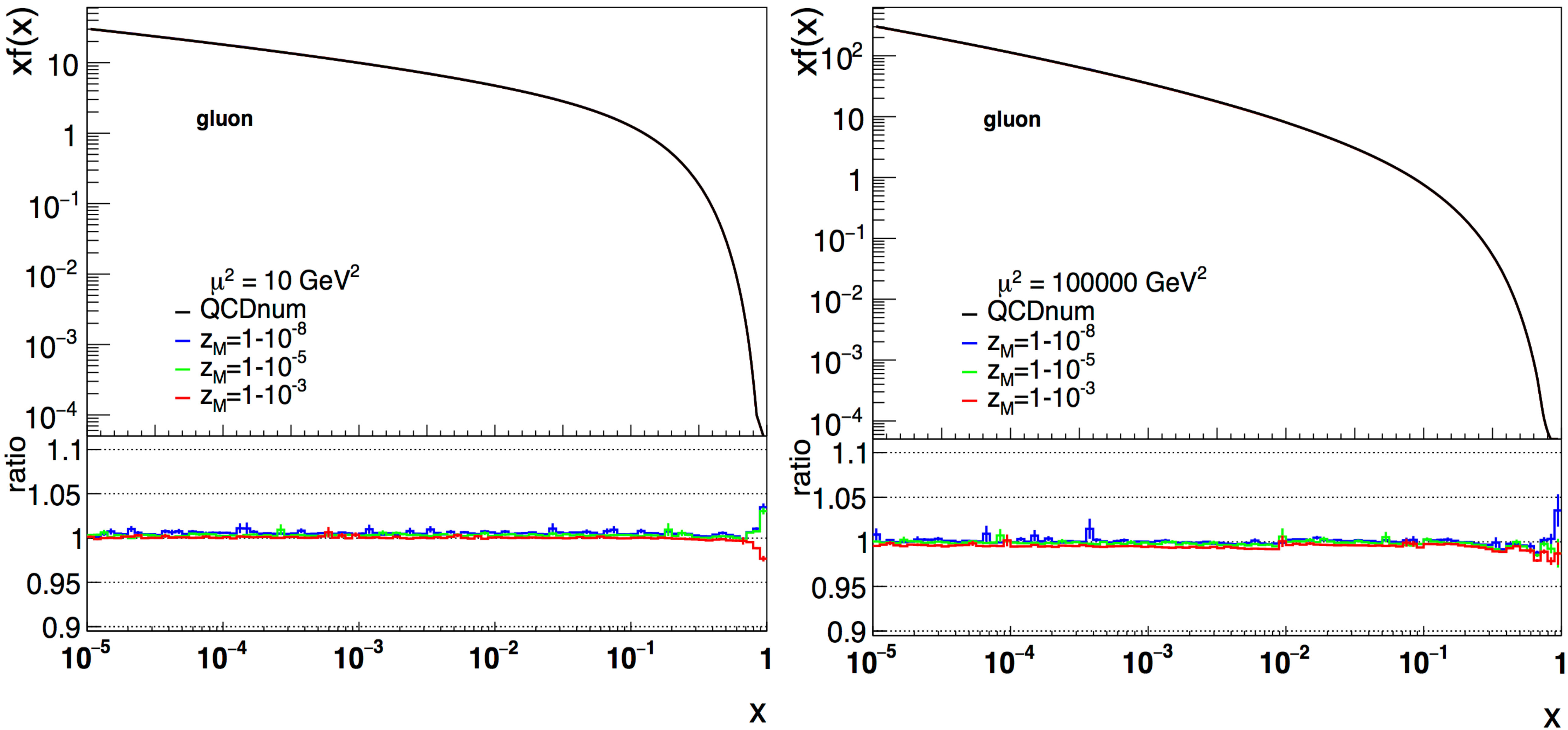
Validation of method with QCDnum at NLO





- Very good agreement with NLO - QCDnum over all x and μ^2
  - the same approach works also at NNLO !

Validation of method at NLO: z_M - dependence



- No dependence on z_M if z_M is large enough:
  - approximation is of
- Very good agreement with NLO - QCDnum

PDFs from Parton Branching method: fit to HERA data

- Convolution of kernel with starting distribution

$$
\begin{aligned}
xf_a(x,\mu^2) &= x\int dx' \int dx'' \mathcal{A}_{0,b}(x') \tilde{\mathcal{A}}_a^b\left(x'',\mu^2\right) \delta(x'x''-x) \\
&= \int dx' \mathcal{A}_{0,b}(x') \cdot \frac{x}{x'}\ \tilde{\mathcal{A}}_a^b\left(\frac{x}{x'},\mu^2\right)
\end{aligned}
$$

- Fit performed using xFitter frame (with collinear Coefficient functions at NLO)
  - using full HERA I+II inclusive DIS (neutral current, charged current) data
    - in total 1145 data points

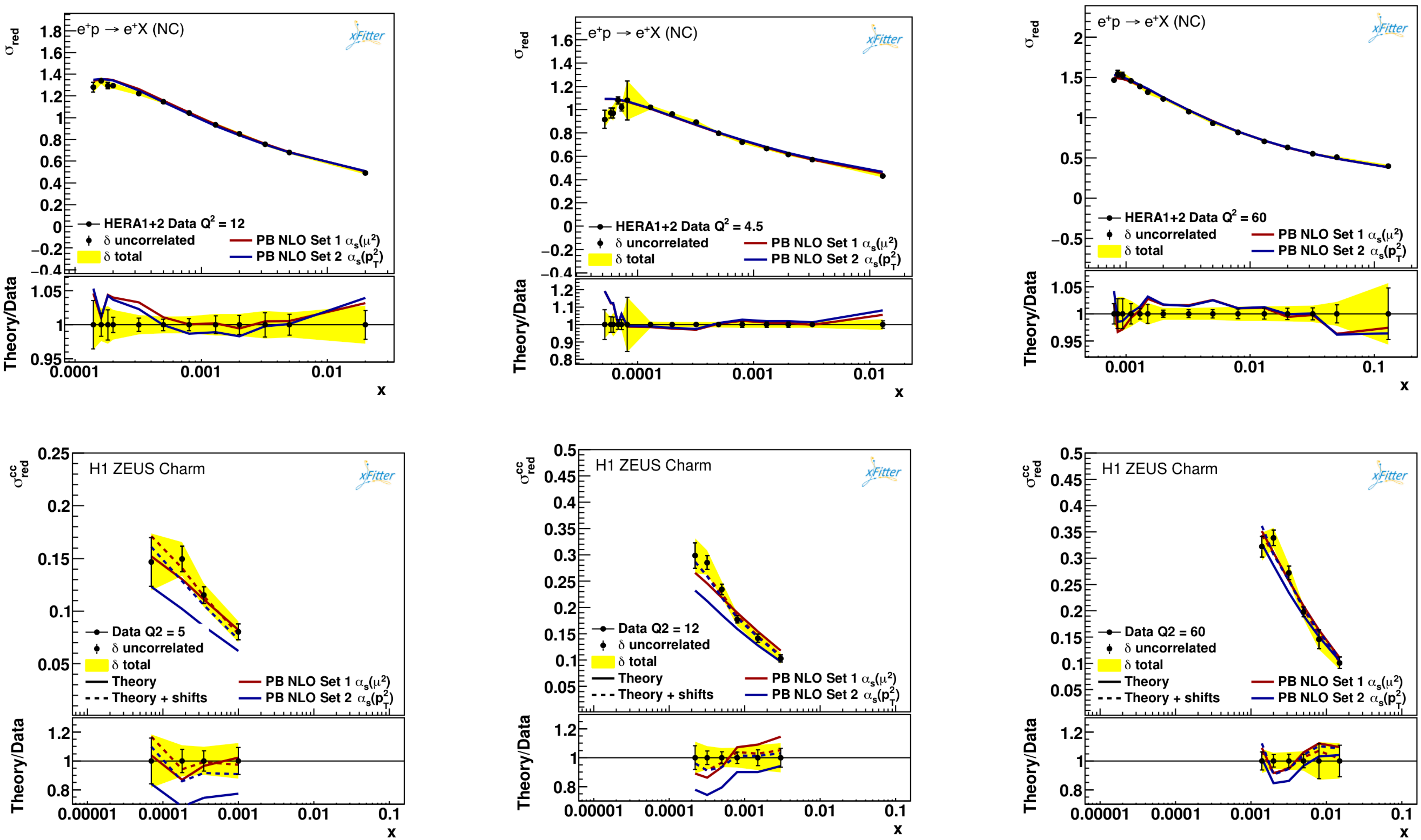
$$3.5 \leq Q^2 \leq 50000\ \mathrm{GeV}^2$$

$$4 \cdot 10^{-5} < x < 0.65$$

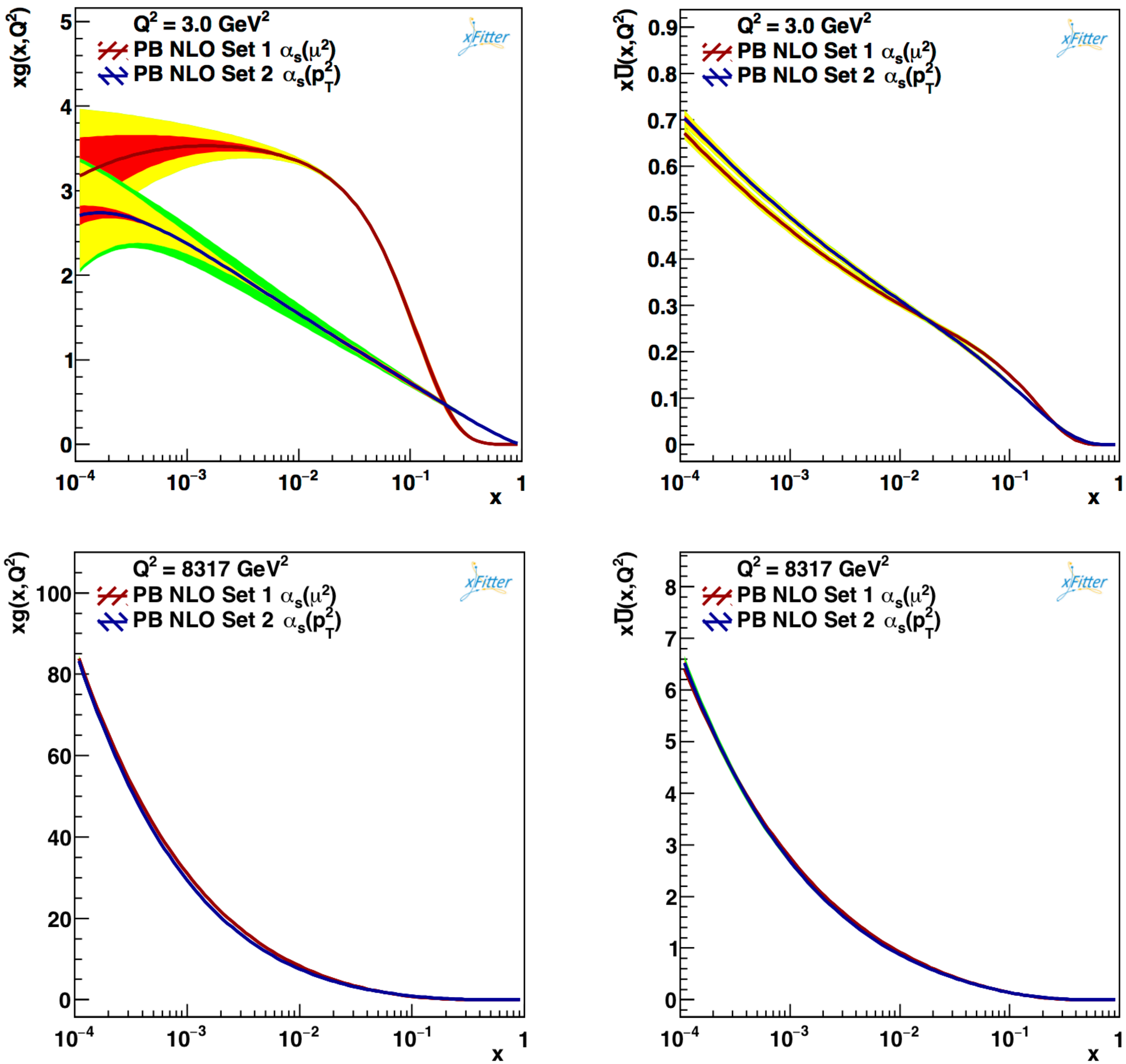
    - using starting distribution as in HERAPDF2.0
    - $\chi^2/ndf = 1.2$

➔ Can be easily extended to include any other measurement for fit !

Fits to DIS x-section at NLO: F_2 and F_2^c

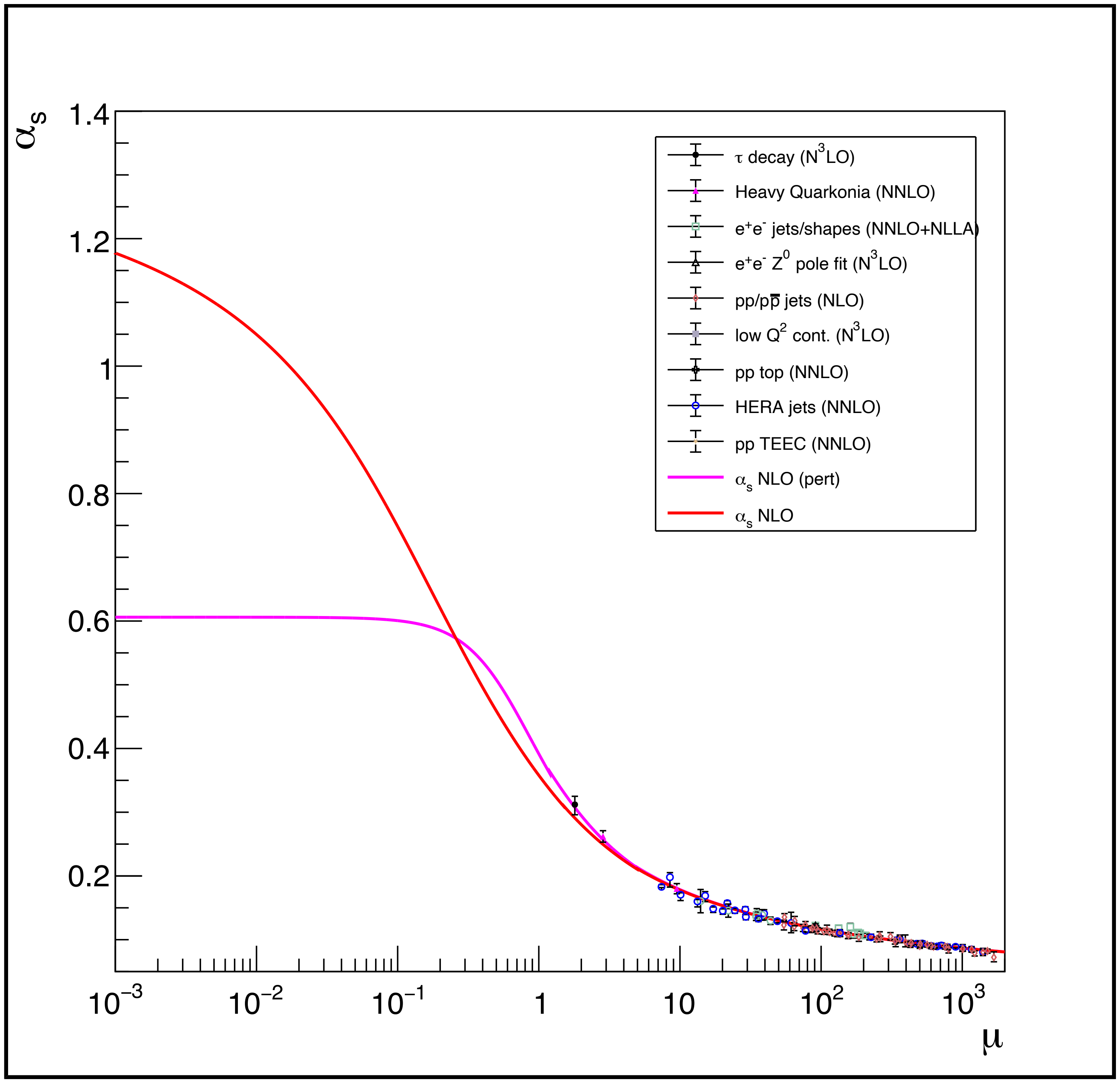


Collinear parton distributions after fit



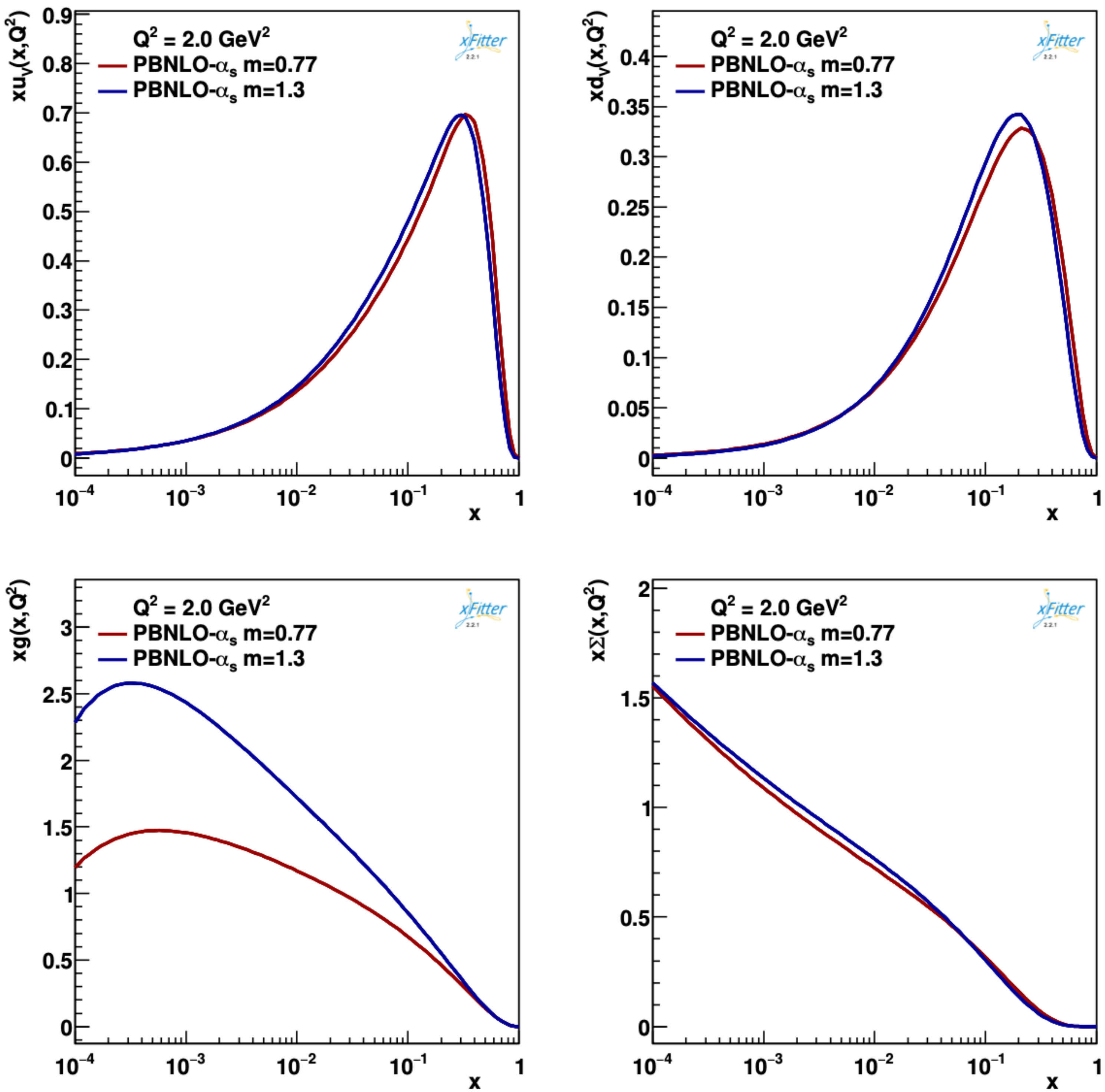
- fit 1 with $\alpha_s(\mu)$
  - $\mu = q$
  - as good as HERAPDF2.0 $\chi^2/ndf = 1.2$
- fit 2 with $\alpha_s(\mu)$
  - $\mu = max(1,q(1-z))$
  - $\chi^2/ndf = 1.21$
- very different gluon distribution obtained at small Q^2

Analytic continuation of α_s into the non-pert region



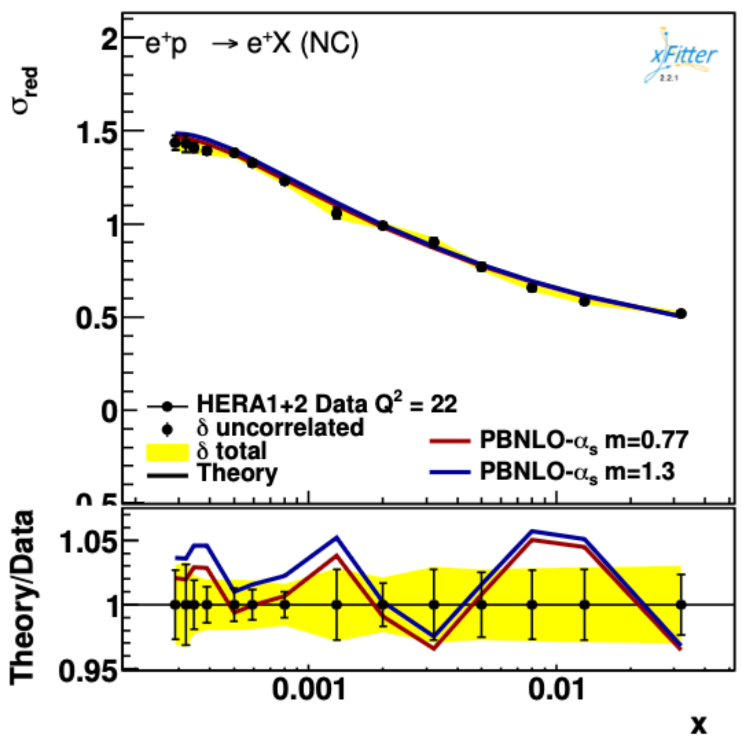
- α_s with extension to small k_T region
  - with taming parameter: $q^2_{eff} = q^2 + m^2_{soft}$ here $m_{soft} = 1$
  - with analytic continuation ala A. Kotikov et al

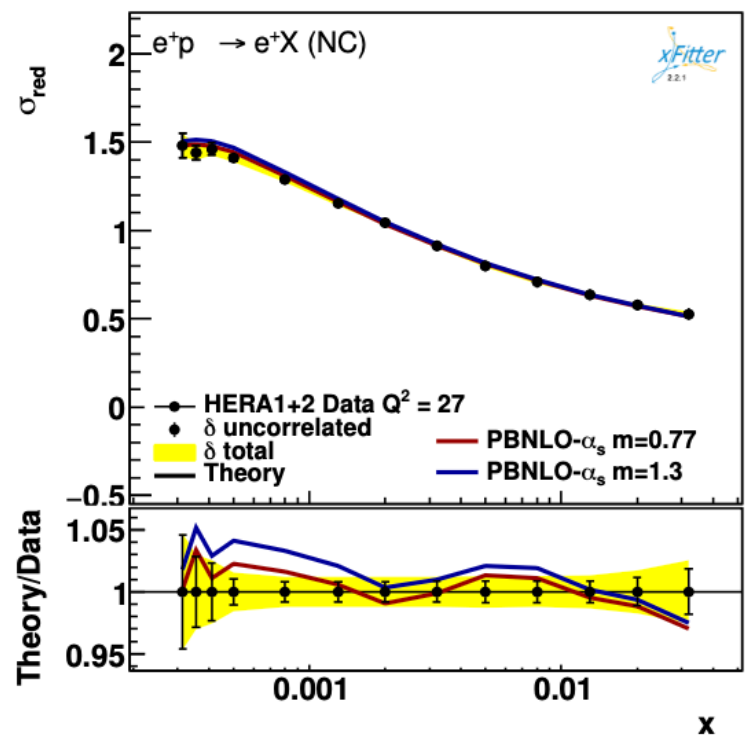
Collinear parton distributions after fit with new α_s

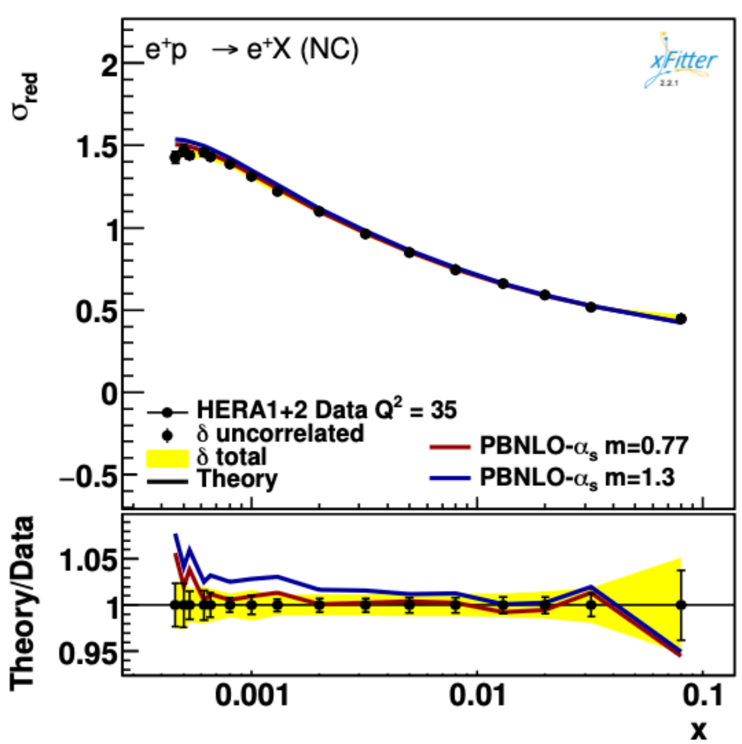


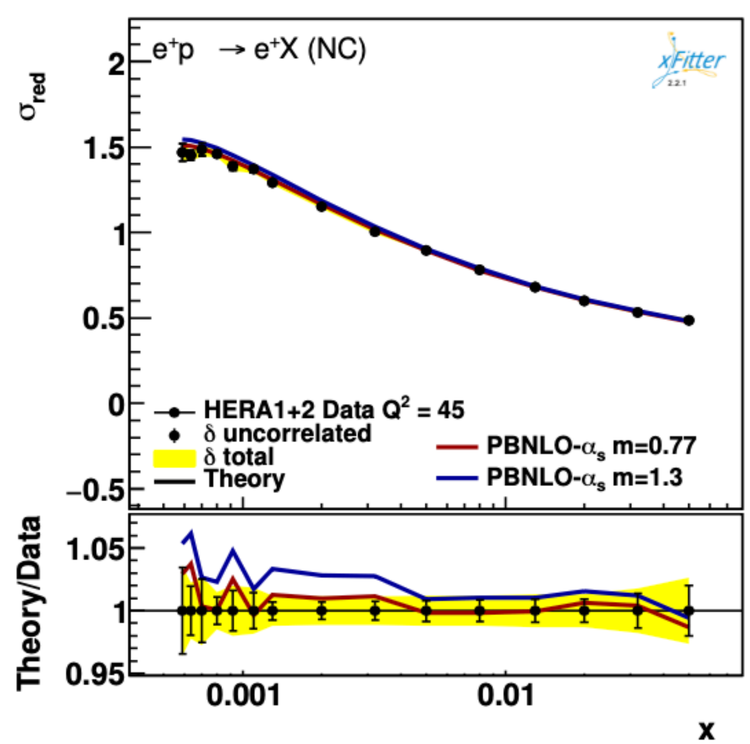
- fit with tamed $m_{soft} = 1$ GeV α_s: $\chi^2/ndf = 1.21$
- fit with tamed $m_{soft} = 0.77$ GeV α_s: $\chi^2/ndf = 1.25$
- fit with tamed $m_{soft} = 1.3$ GeV α_s: $\chi^2/ndf = 1.22$
- fit with analytic α_s: $\chi^2/ndf = 1.75$
  - not really good
  - Especially shape of gluon at starting scale in different !

Fits to DIS x-section at NLO: F_2

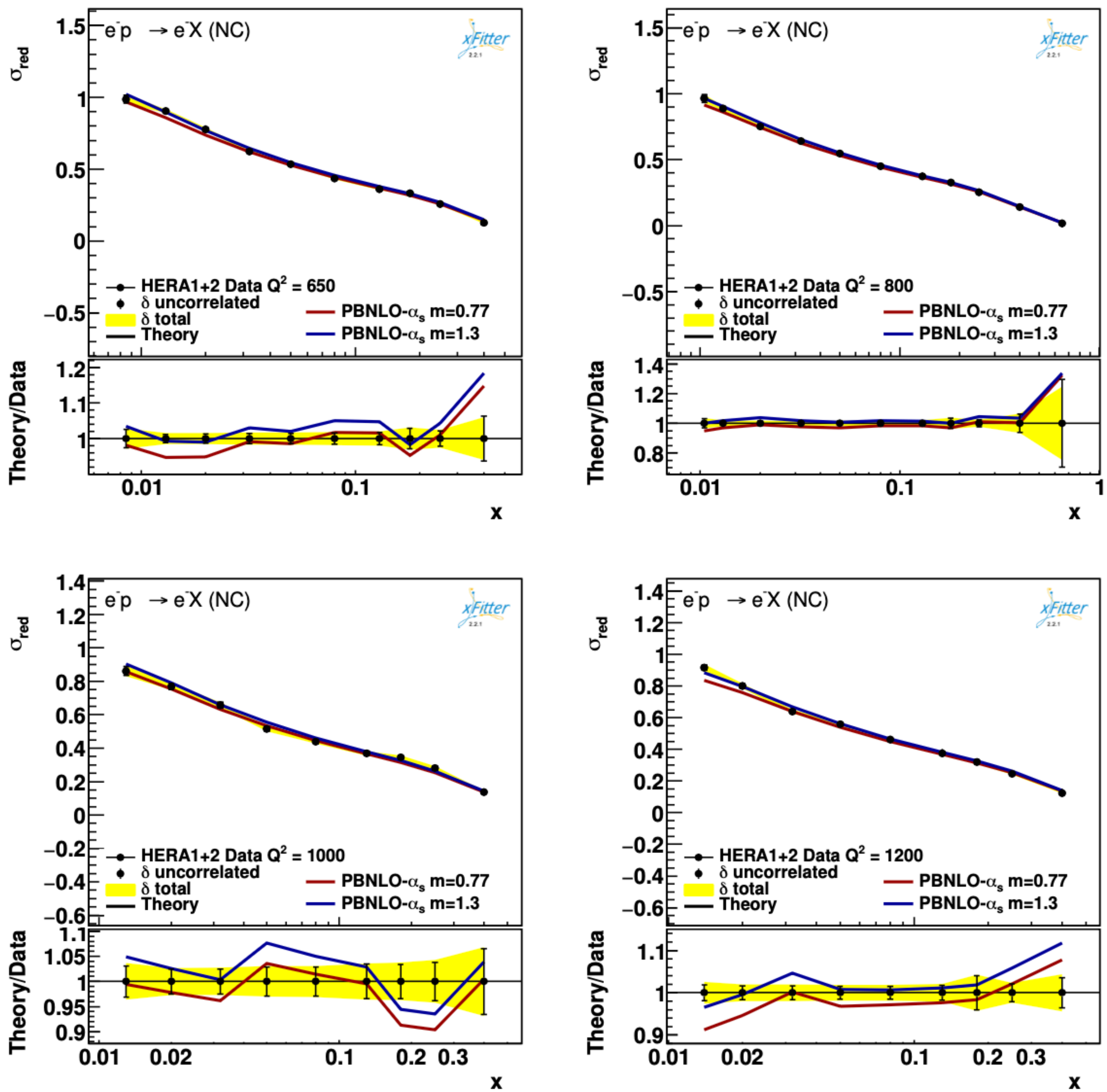




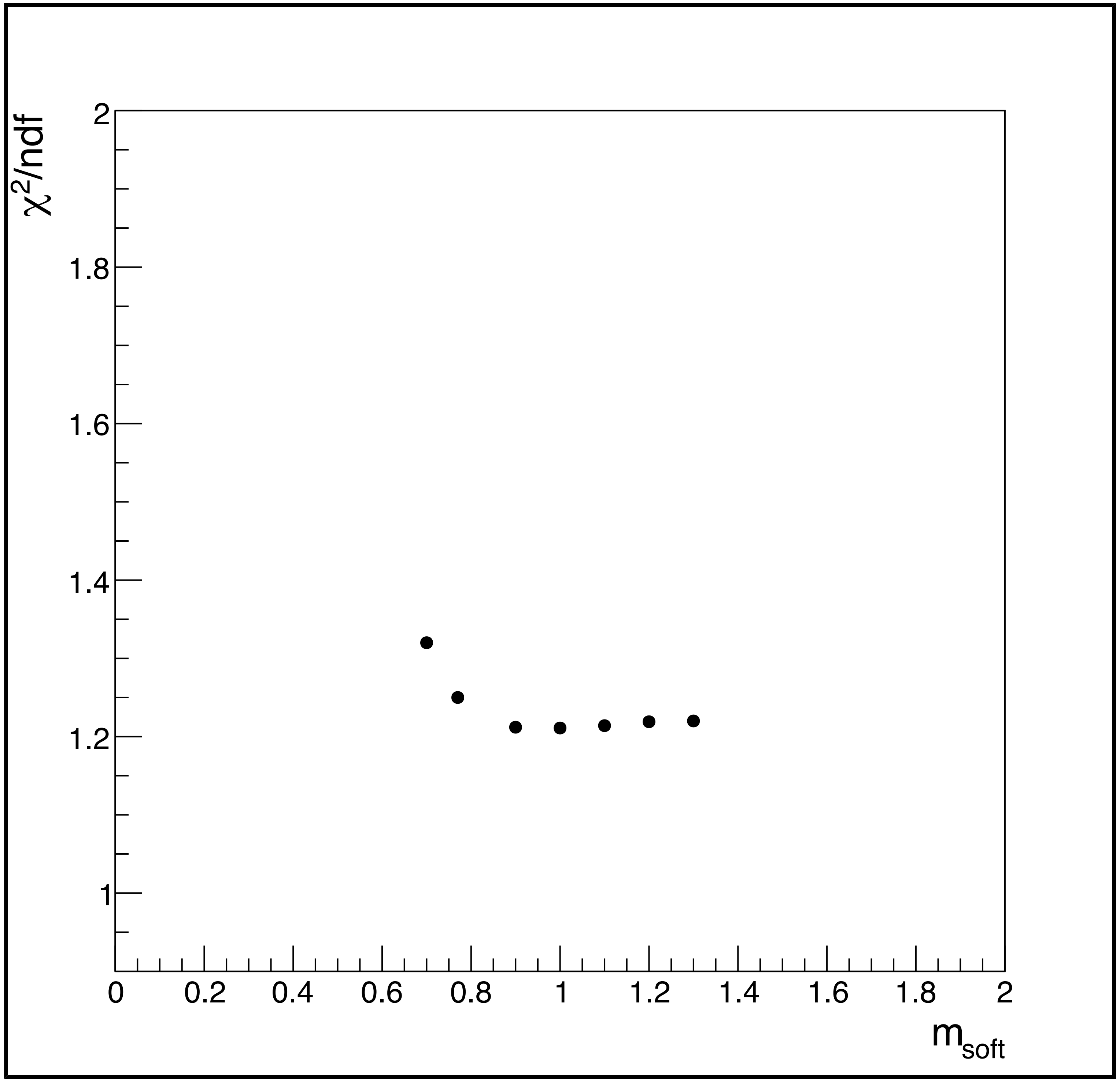




Fits to DIS x-section at NLO: F_2



Fit results with α_s with taming with m_{soft}



Conclusion

- Treatment of small k_T region in QCD fits very important, if scale in α_s is k_T dependent
  - with taming (instead of fixing) α_s already very good fit obtained
  - with analytically continued α_s - difficulty to fit F2 with good chi2
    - shape of gluon at small scales very different

Appendix