Small x Gluon from Exclusive J/ψ Production

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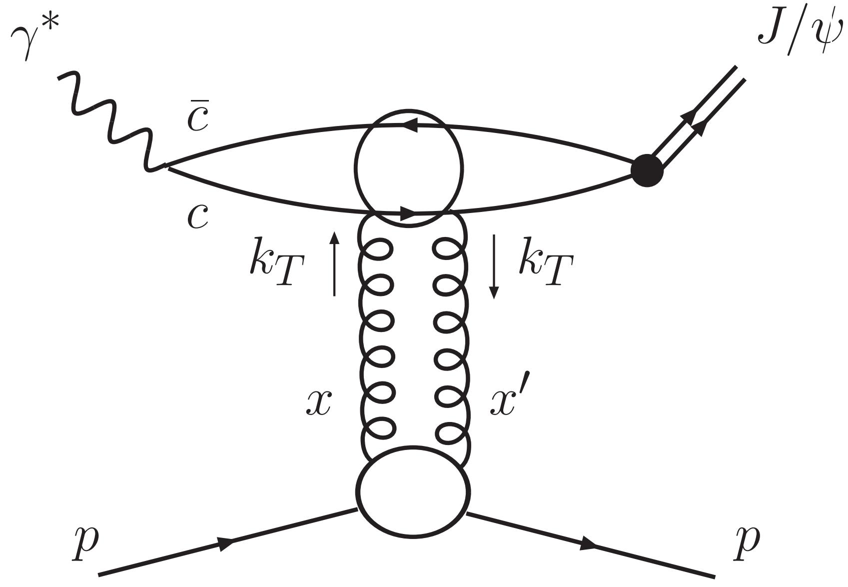
Outline

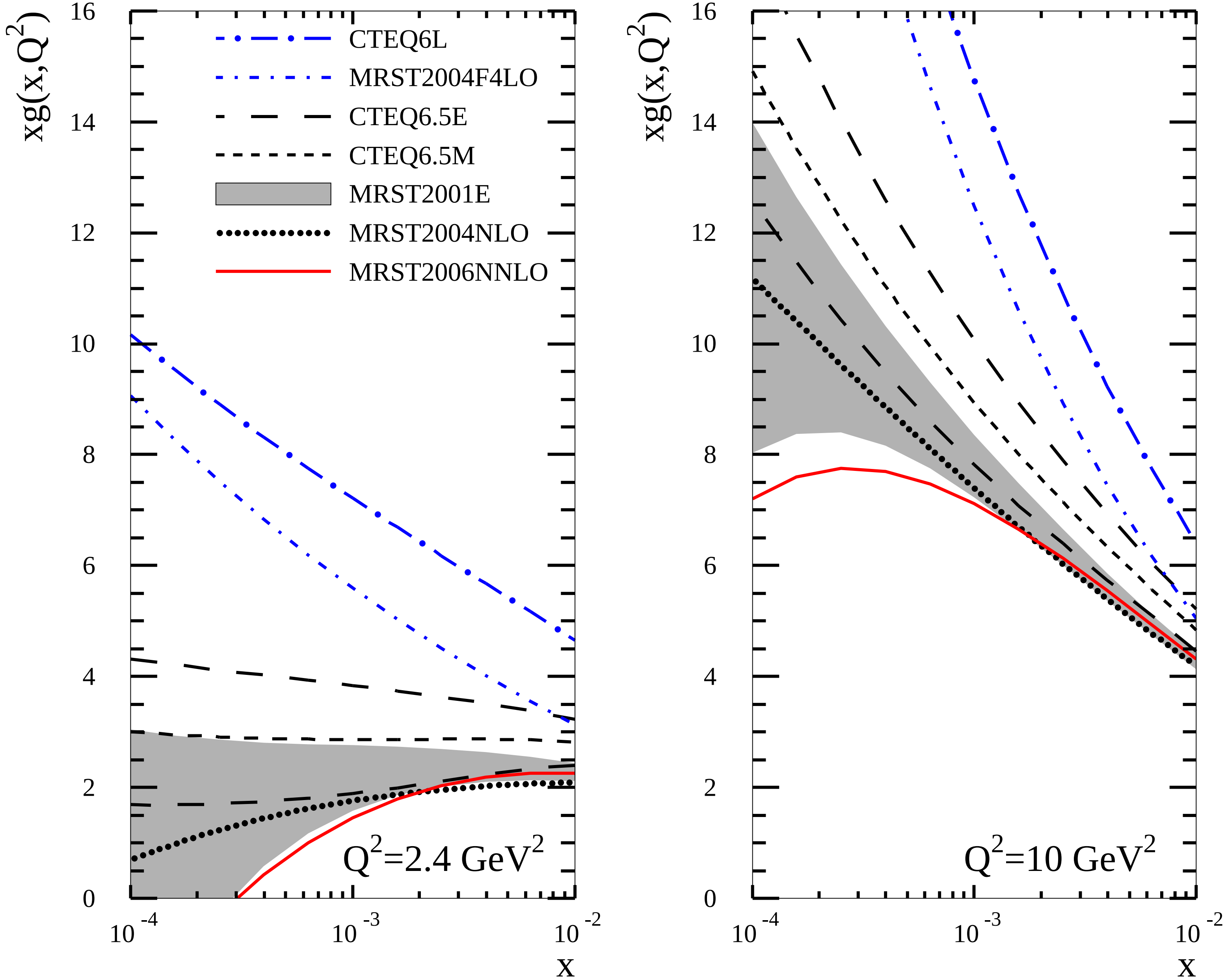
- ⋆ Introduction to high energy diffraction
- ⋆ Motivation
- ⋆ LO and ‘NLO’ approaches
- ⋆ Results
- ⋆ Future work
- ⋆ Summary

High Energy Diffraction

- ⋆ Interest in HERA $\gamma p \to Xp$ data produced at high γp energy, W.
- ⋆ Diffraction: large rapidity gap $\to$ colourless (2g) exchange
- ⋆ Perturbative QCD for exclusive processes: $W \gg Q^2, M^2_{VM}, m^2_q \gg \Lambda_{QCD}$
- ⋆ Non-perturbative part of process: PDFs



Motivation



$xg(x,Q^2)$
CTEQ6L
MRST2004F4LO
CTEQ6.5E
CTEQ6.5M
MRST2001E
MRST2004NLO
MRST2006NNLO
Q^2=2.4 GeV^2
Q^2=10 GeV^2
x

LO Approach

- ⋆ Effective scale $\bar{Q}^2 = (Q^2 + M_\psi^2)/4$ and Bjorken $x = (Q^2 + M_\psi^2)/(W^2 + M_\psi^2)$
- ⋆ LO cross section to leading $\ln(\bar{Q}^2)$ accuracy given by

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t}\left(\gamma^* p \to J/\psi\ p\right)\Big|_{t=0} = \frac{\Gamma_{ee} M_{J/\psi}^3 \pi^3}{48\alpha}\left[\frac{\alpha_s(\bar{Q}^2)}{\bar{Q}^4} xg(x, \bar{Q}^2)\right]^2 \left(1 + \frac{Q^2}{M_{J/\psi}^2}\right)$$

- ⋆ At small x assume power dependence: $xg(x, \mu^2) \ = \ N x^{-\lambda}$ with $\lambda = a + b\ \ln(\mu^2/0.45\ \mathrm{GeV}^2)$
- ⋆ Include real part of amplitude and skewing correction, approximated by

$$R_g = \frac{2^{2\lambda+3}}{\sqrt{\pi}} \frac{\Gamma(\lambda + \frac{5}{2})}{\Gamma(\lambda + 4)}$$

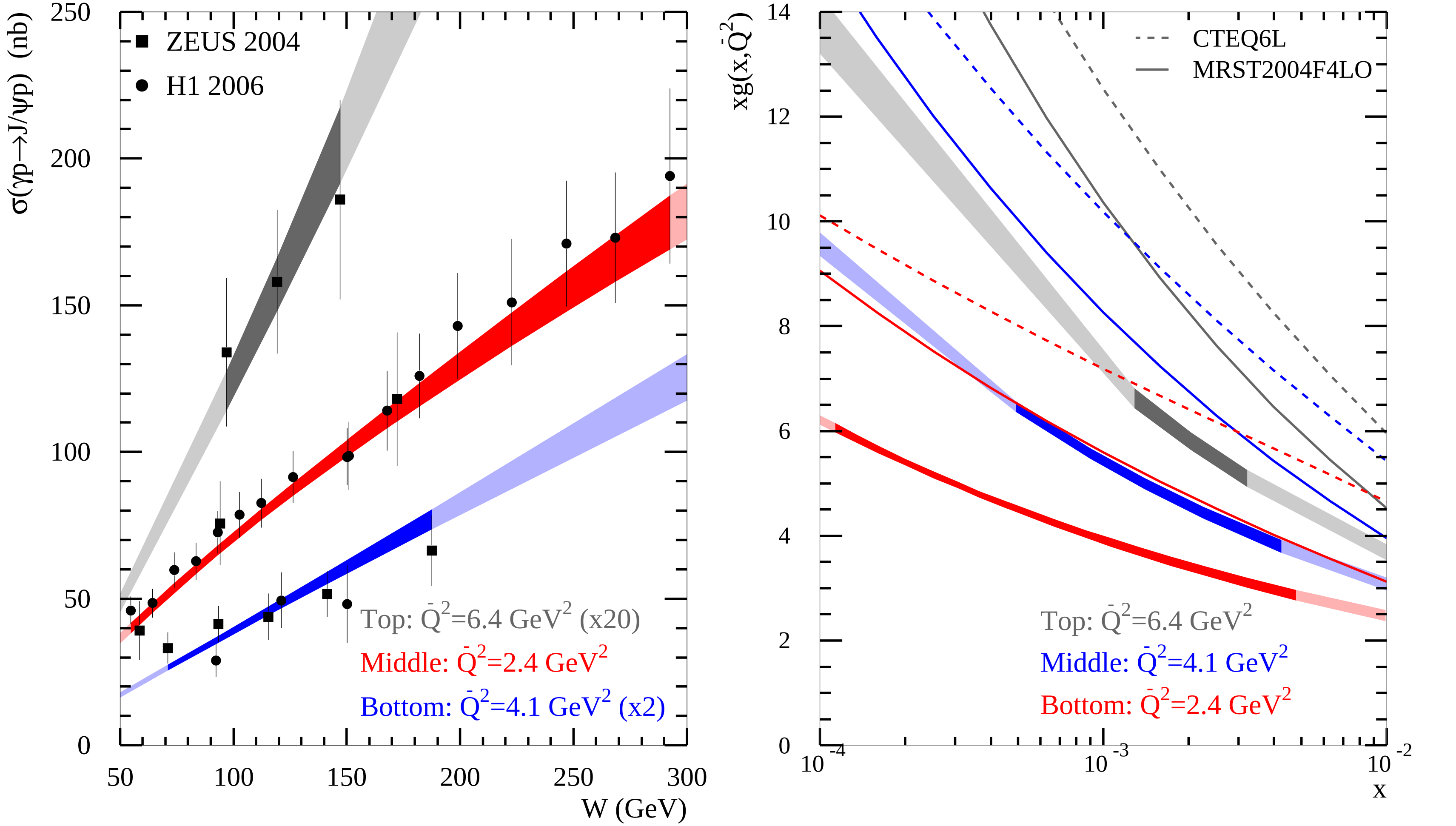
NLO Approach

- ⋆ Beyond the leading $\ln(\bar{Q}^2)$ approximation: use of unintegrated gluon from explicit integration over gluon k_T

$$xg(x,\mu_2^2) = c(\mu_1^2) + \int_{\mu_1^2}^{\mu_2^2} \frac{dk_T^2}{k_T^2} f(x,k_T^2)$$

- ⋆ For fits we use
  $xg(x,\mu^2) \;=\; Nx^{-\lambda}$ with $\lambda = a + b\,\ln\ln(\mu^2/0.09\ \mathrm{GeV}^2)$
- ⋆ Real part of amplitude, skewing corrections and Sudakov factor included in fits.

LO Results



ZEUS 2004
H1 2006
σ(γp→J/ψp) (nb)
W (GeV)
Top: $\bar{Q}^2$=6.4 GeV^2 (x20)
Middle: $\bar{Q}^2$=2.4 GeV^2
Bottom: $\bar{Q}^2$=4.1 GeV^2 (x2)
CTEQ6L
MRST2004F4LO
$xg(x,\bar{Q}^2)$
x
Top: $\bar{Q}^2$=6.4 GeV^2
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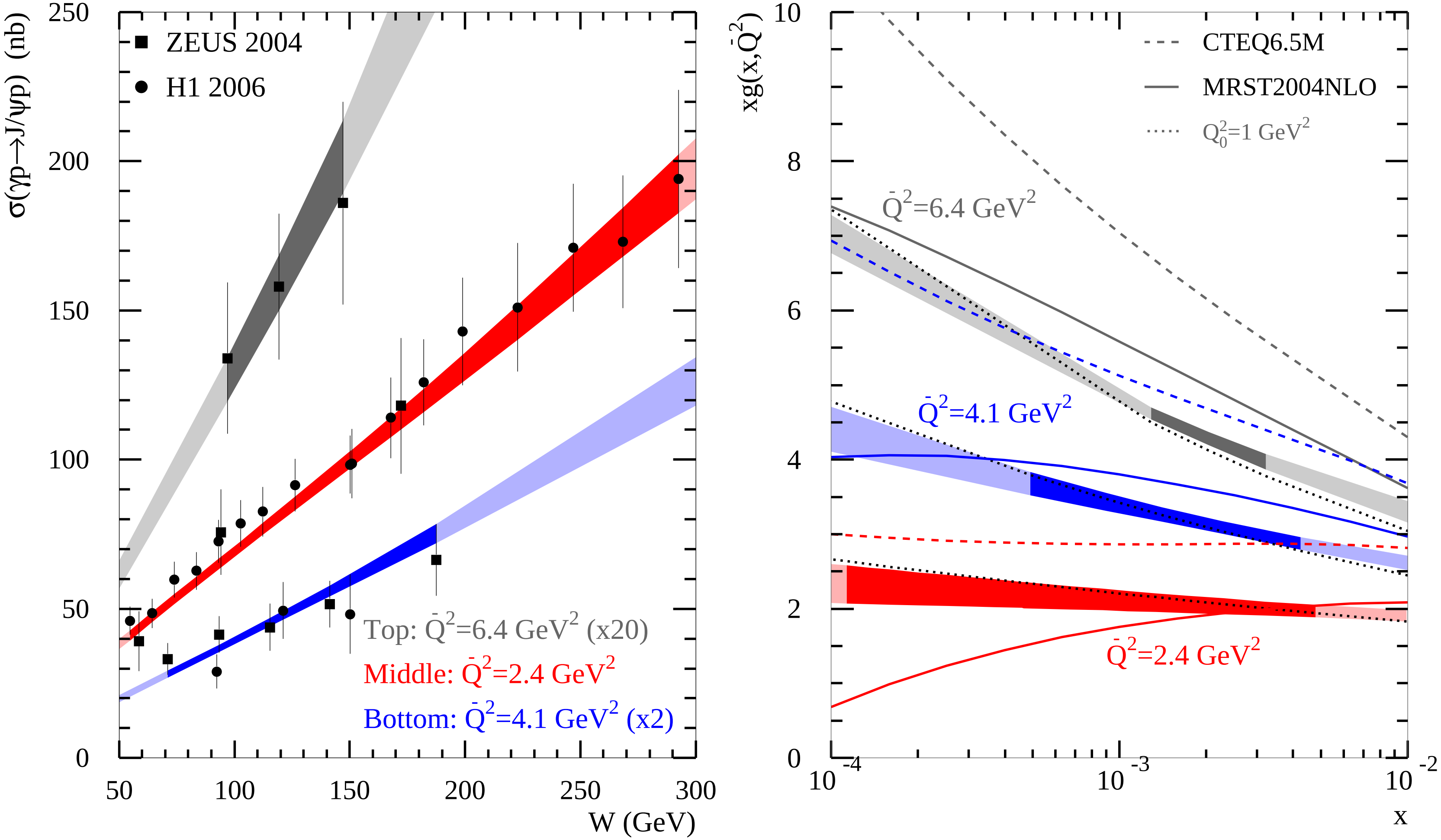
Bottom: $\bar{Q}^2$=2.4 GeV^2

NLO Results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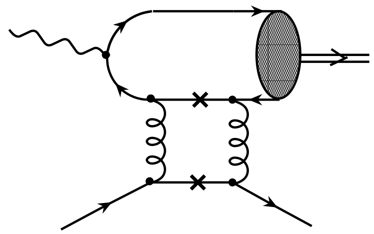
Bottom: $\bar{Q}^2$=4.1 GeV^2 (x2)
xg(x,$\bar{Q}^2$)
x
CTEQ6.5M
MRST2004NLO
Q_0^2=1 GeV^2
$\bar{Q}^2$=6.4 GeV^2
$\bar{Q}^2$=4.1 GeV^2
$\bar{Q}^2$=2.4 GeV^2

Future Work

- ⋆ For full NLO calculation, we need to estimate the quark contribution to the amplitude



- ⋆ However, our skewing estimation R_q is not sufficient for larger x, need to use ‘off forward’ quark distributions
- ⋆ Can subtract off the quark contribution from the data, rather than include in the fit

Summary

- Our gluons are flatter than the global fits, both in x dependence and the scale dependence $\lambda(\bar{Q}^2)$
- Fair agreement in evolution between our NLO gluon and the CTEQ fit. In absolute normalisation our gluon compares better to the MRST NLO prediction
- The accuracy of the elastic J/ψ data constrains the small x gluon sufficiently, especially in comparison to inclusive DIS structure function data used by global analyses
- Our analysis of elastic J/ψ data is valuable to constrain the gluon in the region $10^{-4} \lesssim x \lesssim 10^{-2}$ and $2 \lesssim \mu^2 \lesssim 10 \text{ GeV}^2$

Theoretical Uncertainties

Vary renormalisation scale of α_S and scale in Sudakov factor from $0.5\mu^2..2\mu^2$. Error bands estimate an uncertainty of about $\pm 20\%$.