Using the elastic $\gamma^* p \rightarrow J/\psi p$ cross-section to probe the small x gluon density

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September 5th 2013

Outline

Introduction.

Motivation

- Deep inelastic scattering data (e.g. from HERA) poorly constrains the gluon density at low scales ($\mu^2 < 6$ GeV^2) and small x ($\sim 10^{-4}$)

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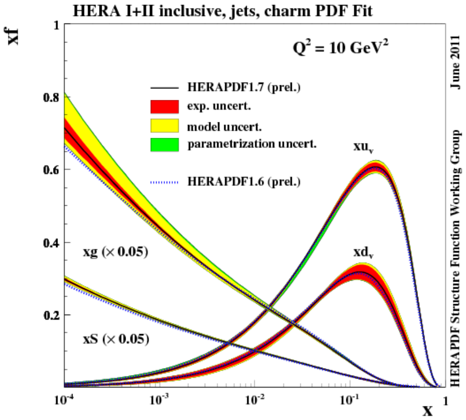

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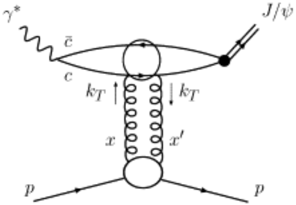
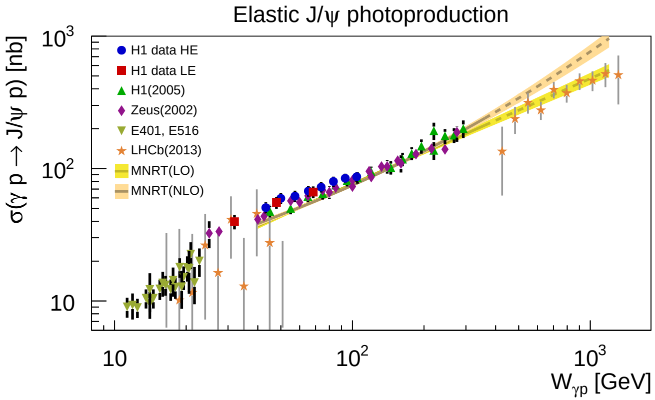
- Exclusive processes such as exclusive heavy vector meson production should be a sensitive probe of the gluon in this domain
- Can such processes constrain the gluon?

Photoproduction of J/ψ



- $\gamma^* p \rightarrow J/\psi p$
- Photoproduction of a $c\bar{c}$ state (Dipole model)
- Colorless two gluon (pomeron) exchange with the proton
  $\rightarrow$ **Squared** dependency of the gluon distribution in the proton
- J/ψ in the final state

Situation so far



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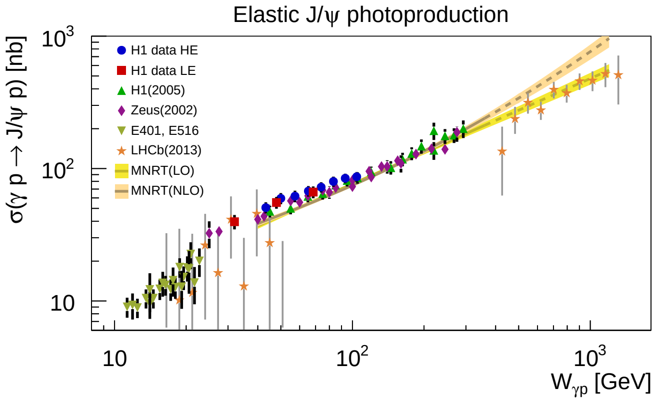

- So far: Few PDFs able to describe new data, especially NLO not
- Quite some theoretical interest in this
- Two papers published, while we were here

Theory.

Leading logarithmic order theory

Differential cross-section

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

[a] S.P. Jones, A.D. Martin, T. Teubner et. al.

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$$\bar{Q}^2 = (Q^2 + M_{J/\psi}^2)/4, \quad x = (Q^2 + M_{J/\psi}^2)/(W^2 + Q^2).$$

Q^2: virtuality of the photon, $W_{\gamma p}$: center-of-mass energy.

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For t integration assume $\sigma \propto \exp(-Bt)$, with B the slope parameter:

$$B(W) = (b_0 + 4\alpha' \ln(W/90\mathrm{GeV}))\,\mathrm{GeV}^{-2}$$

Procedure

Aim

- calculate cross-section with different LO gluon densities

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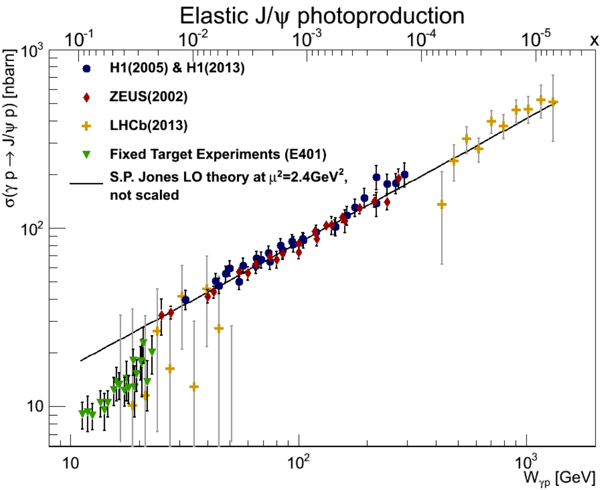
- calculate cross-section with different LO gluon densities

Gluon densities

- S.P. Jones LO (Theory)
- HERAPDF-like LO parametrisation
- CTEQ6l (LO, except for α_s)

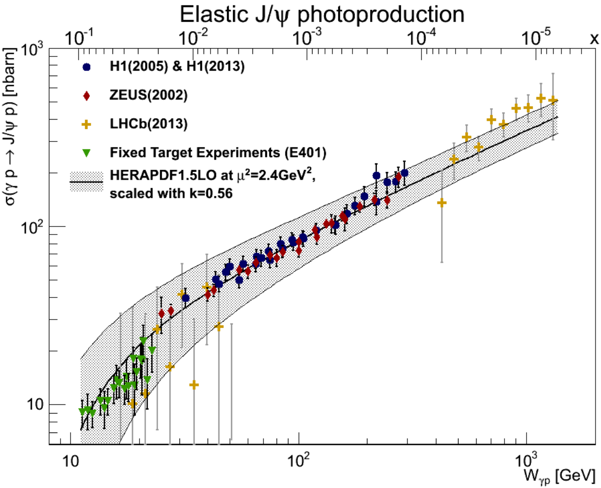
Results.

Using theoretical LO prediction



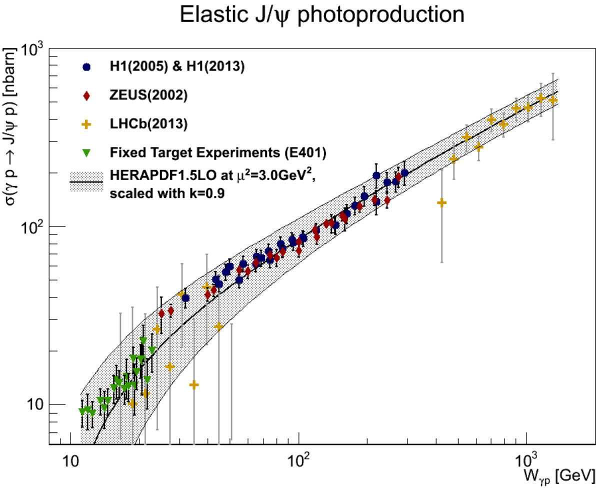
$$g(x,\mu^2) = Nx^{-\lambda} \quad \rightarrow \quad \sigma(W_{\gamma p}) = N' W^{-\delta}, \quad \delta = 4\lambda$$

Using HERAPDFLO at μ^2=2.4 GeV^2



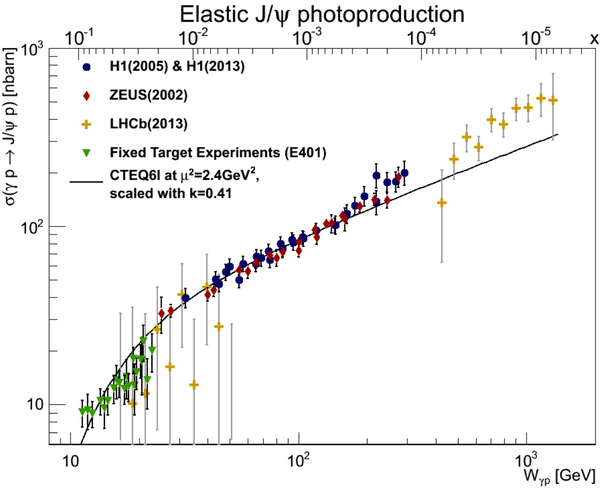
Using $k = 0.56 \pm 0.01$ for normalization

Using HERAPDFLO at μ^2=3 GeV^2



Using $k = 0.91 \pm 0.01$ for normalization

Comparison with CTEQ6l



Using $k = 0.41$ for normalization

Summary

General

- Factorization scale and therefore normalization not exactly known.
- The $W_{\gamma p}$-dependency of the cross-section yields the x-dependency of the gluon density, down to low x.

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HERAPDF LO parametrization

- J/ψ cross-section not a straight line anymore in LO.
- Good agreement with low $W_{\gamma p}$ solutions from LHCb data and with data from fixed target experiments, when choosing different scale.
- Also good agreement with high $W_{\gamma p}$ (low x) solutions from LHCb.
- Better agreement than CTEQ6l.

Thank you for your attention.

Backup.

Correction factors

Skewed gluon distribution

- It is more likely, that one gluon has a significantly lower x
- This can be estimated by multiplying with:

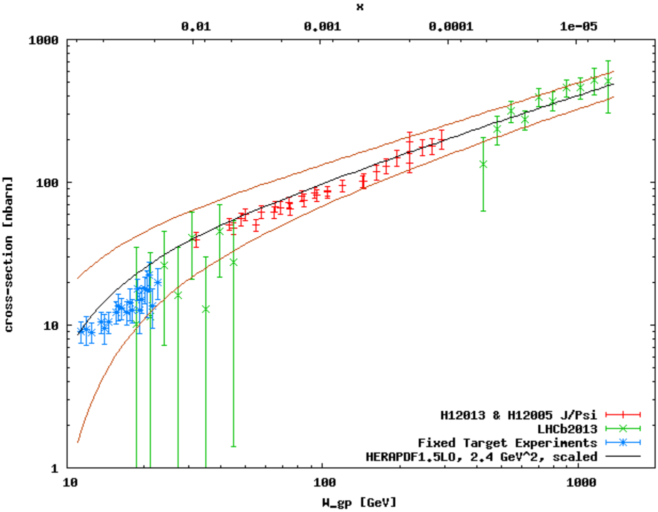
$$R_g = \frac{2^{2\lambda+3}}{\sqrt{\pi}} \frac{\Gamma(\lambda + \frac{5}{2})}{\Gamma(\lambda + 4)}$$

Real Part

- The gluon PDF correpsonds only to the imaginary part of the amplitude
- Using: $\frac{\Re A}{\Im A} \approx \frac{\pi}{2}\lambda$
- And therefore multiplying with:

$$1 + \tan^2\left(\frac{\pi}{2}\lambda\right)$$

with x axis



x
0.01
0.001
0.0001
1e-05
1000
100
10
1
cross-section [nbarn]
10
100
1000
W_gp [GeV]
H12013 & H12005 J/Psi
LHCb2013
Fixed Target Experiments
HERAPDF1.5LO, 2.4 GeV^2, scaled

Comparison between NLO and LO PDF