Has our J/ψ data sensitivity to the gluon density?

- results of a recent study -

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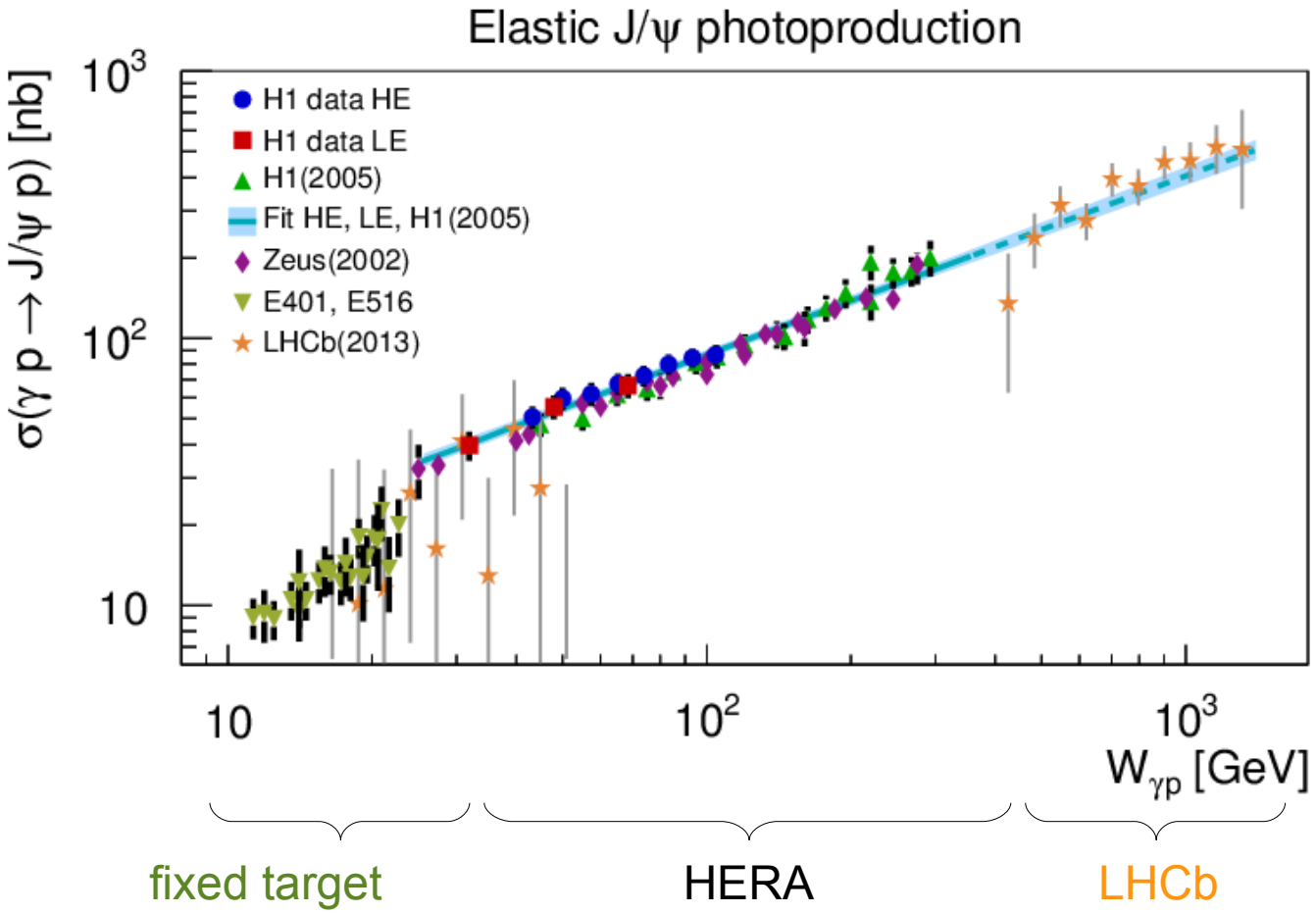
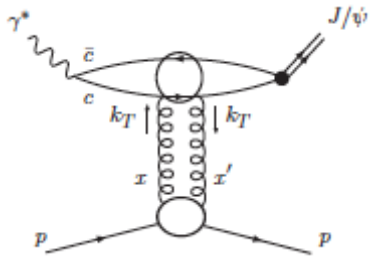
HERA J/ψ data compared to fixed target and LHCb data

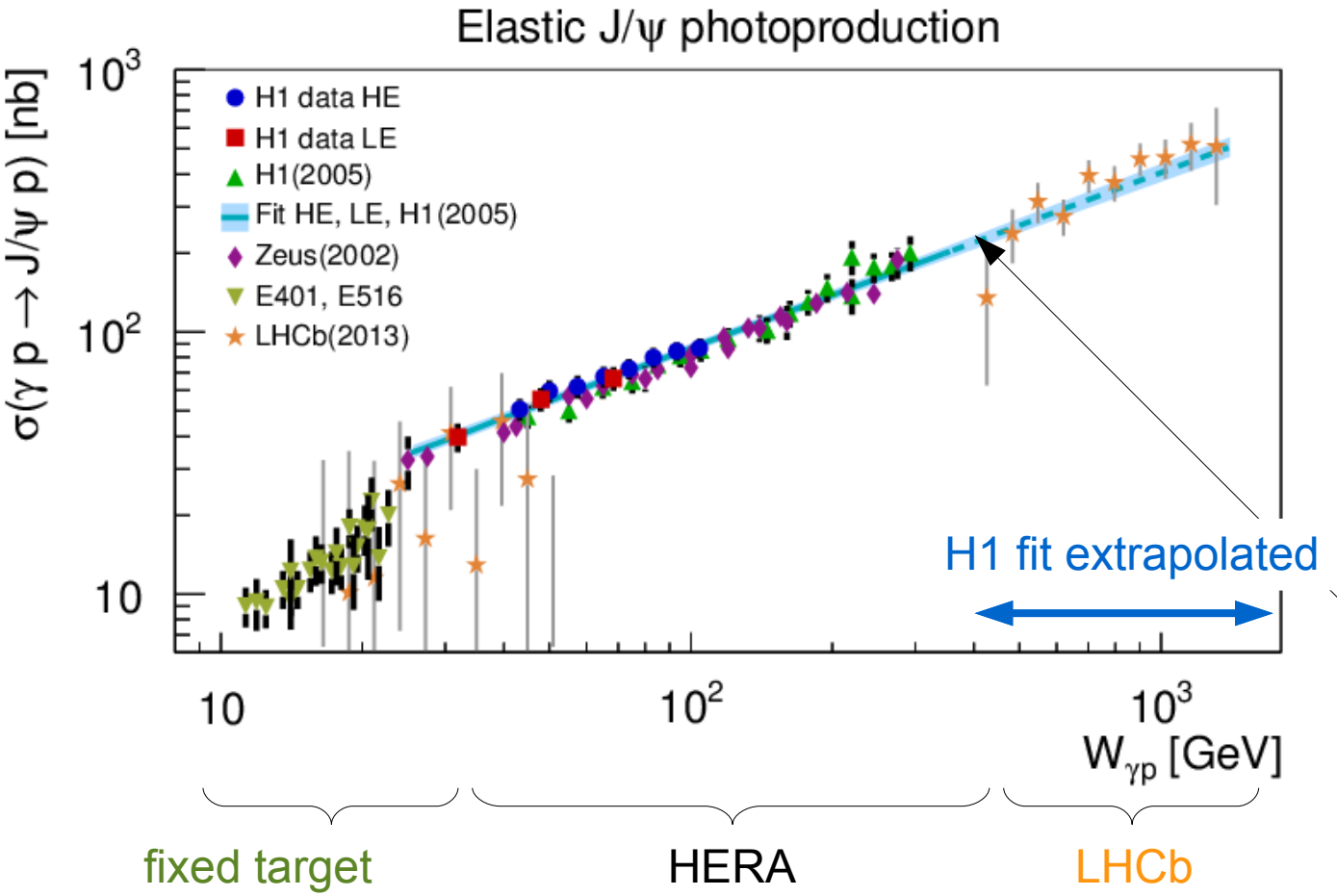


PRL 48 (1982) 73
PRL 52 (1984) 795
arXiv: 1301.7084

- New measurement in the transition region of the fixed target and the previous HERA data.
- Fixed target data: seem to have a steeper slope and lower normalization.
- Fit to H1 data extrapolated to higher $W_{\gamma p}$ values: describes the LHCb data.

Sensitivity to the gluon density





A.Martin et al., arXiv:0709.4406:

$\sigma \propto [x*g(x,\mu^2)]^2$

See also talk from Stephen Jones

H1 fit:

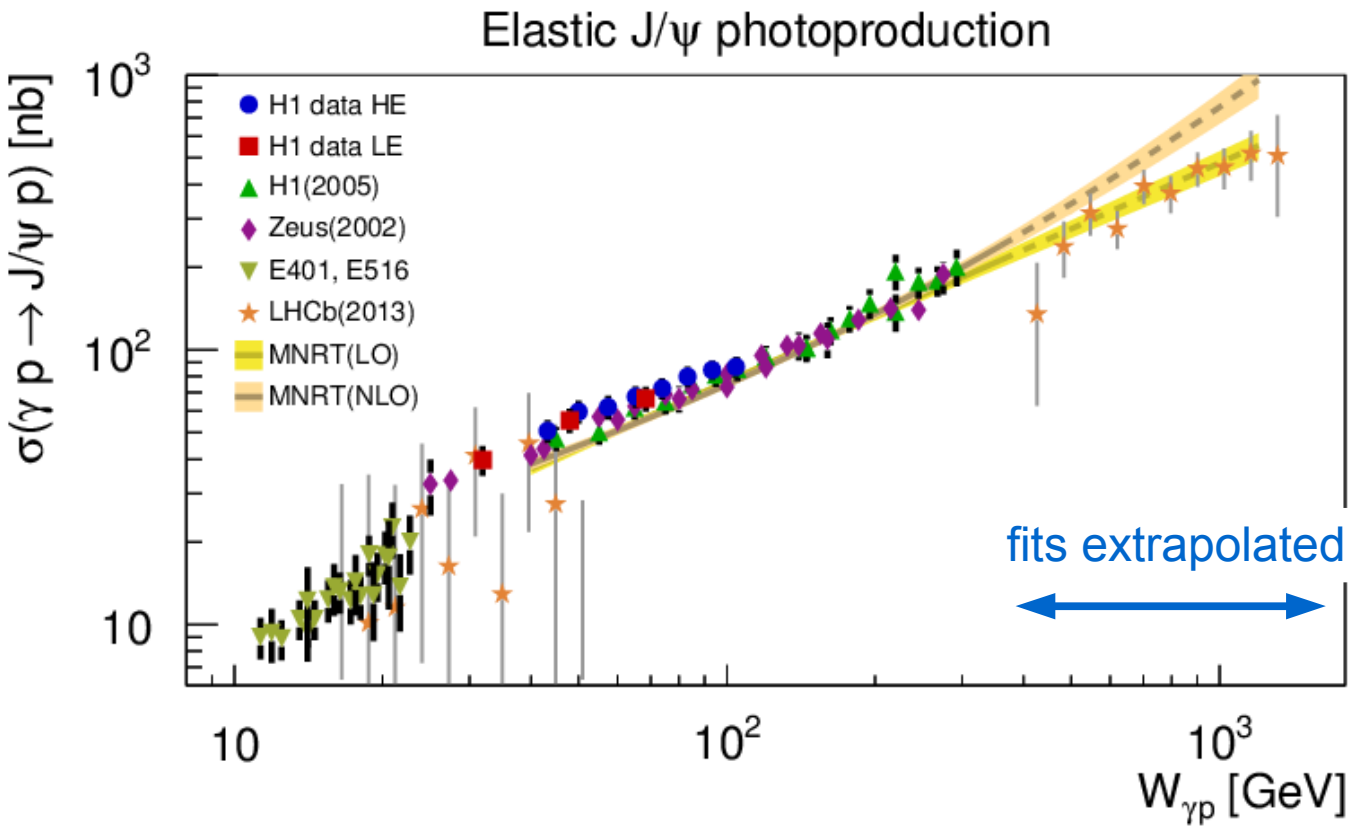
$\sigma = N (W_{\gamma p} / W_0)^{\delta}$

with $W_0 = 90\text{GeV}$

- Following A. Martin et al., δ can be related to a LO gluon density as $x*g(x,\mu^2)=N*x^{-\lambda}$ via $\delta \approx 4*\lambda$, $\mu^2=(Q^2+M_{J/\psi}{}^2)/4$, $W_{\gamma p} \propto 1/\sqrt{x}$.
- λ from this fit $\lambda_{J/\psi}(\mu^2=2.4\text{GeV}^2)=0.168\pm0.008$ agrees to previous fits to inclusive DIS data $\lambda_{J/\psi}(Q^2=2.5\text{GeV}^2)=0.166\pm0.006$.

DESY-08-171, arXiv:0904.0929

Comparison to previous fits based on QCD calculations



A.Martin et al.,
arXiv:0709.4406

- LO and NLO fit to previous J/ψ data and extrapolated to higher $W_{\gamma p}$.
- LO fit describes the LHCb data.
- High precision J/ψ data give important input to gluon density at low x:
  → with the HERA J/ψ data one could reach $x \approx 10^{-5}$, with the LHCb data $x \approx 10^{-6}$.

- New fit since then, look @ backup and talk of Stephen Jones

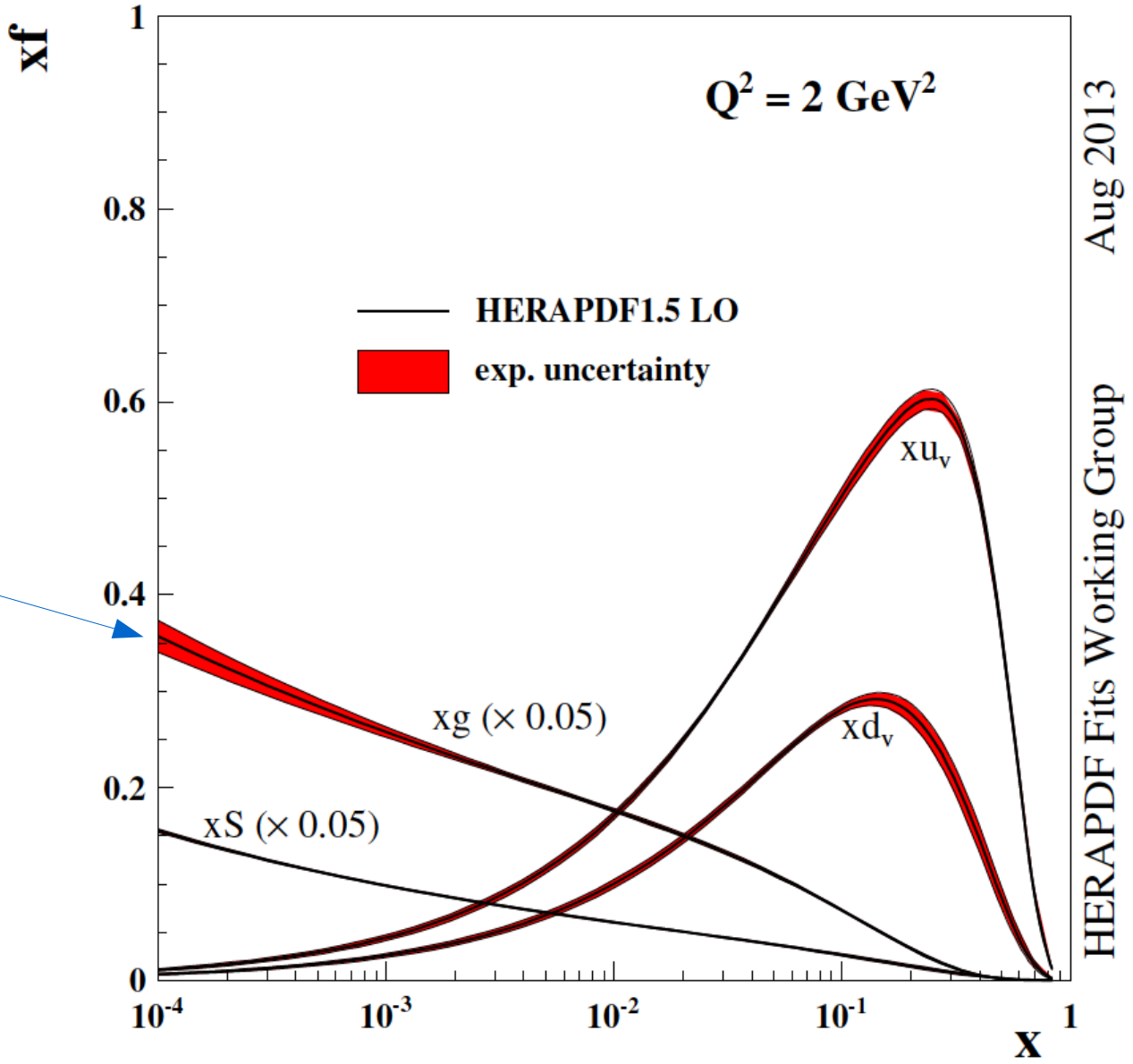
HERAPDF1.5 LO

Approval request for HERAPDF1.5 LO PDF set in the LHAPDF repository

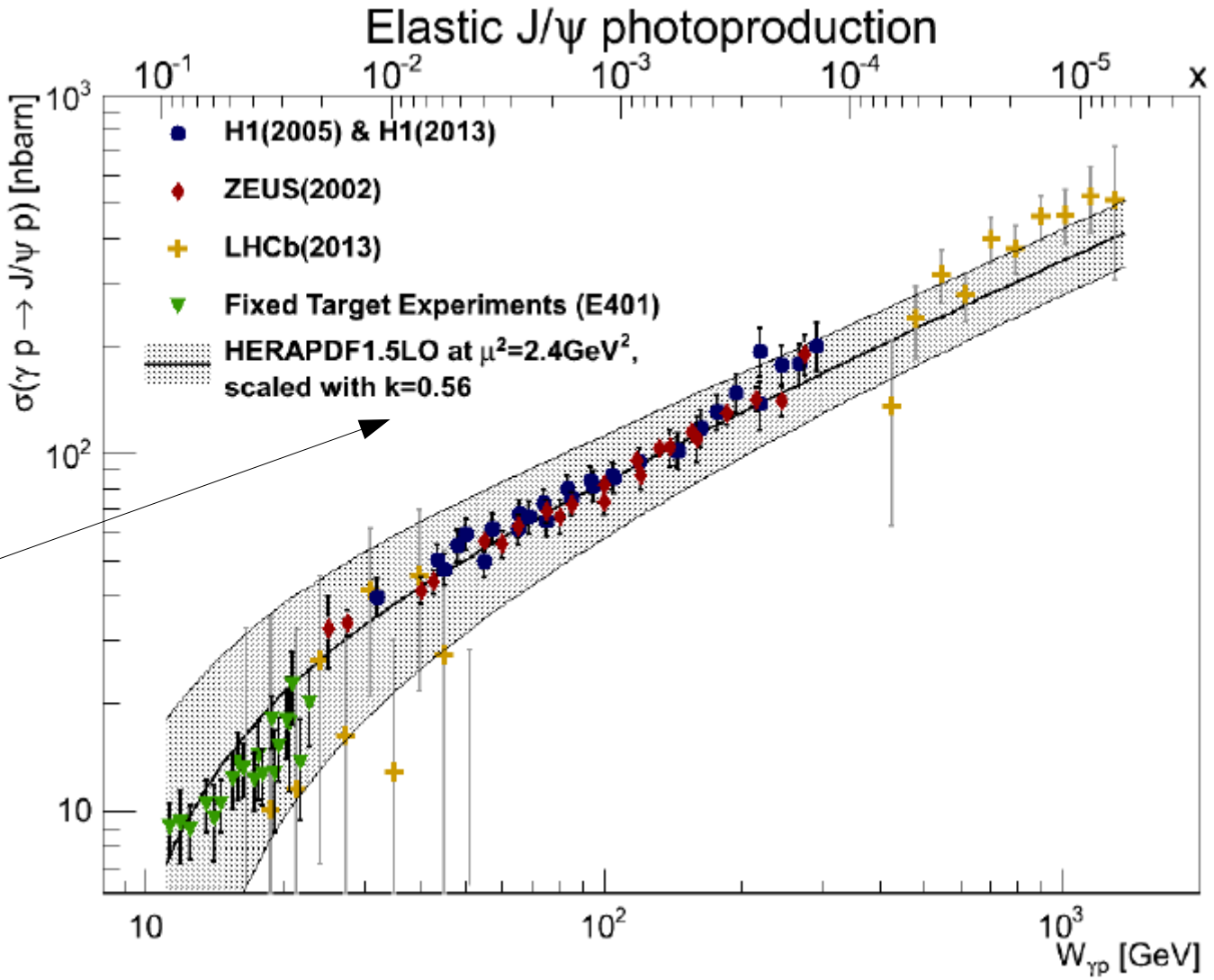
Date: August 30, 2013
Version: 0.3
Editors: V. Radescu,A. Cooper-Sarkar, H. Jung, K. Wichmann
Referees:
Comments by Deadline

HERAPDF1.5LO PDF Set with Experimental Uncertainties

How does this gluon compare to the J/ψ data?



Comparison to HERAPDF1.5, at $\mu^2 = 2.4\text{GeV}^2$, scaled

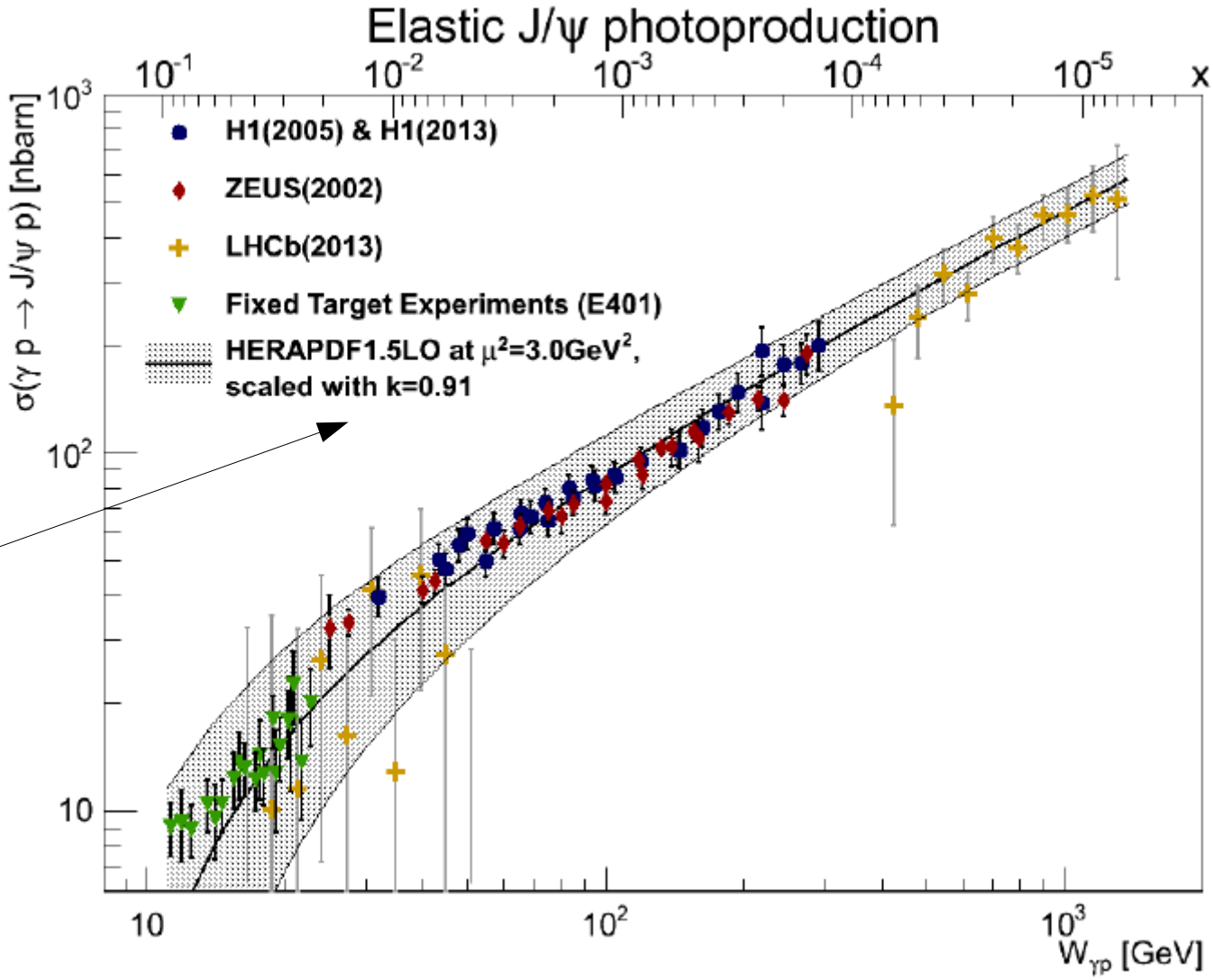


Normalization scaling factor k=0.56

- Scale $\mu^2 \sim 2.4\text{GeV}^2$ for J/ψ photoproduction (Q^2=0GeV^2) due to charm mass.
- Not that well known? (→ S. Jones)
- $\sigma \propto \mu^8$ → normalization depends strongly on the scale μ^2.

Plots from Andreas Weiden (summer student)

Comparison to HERAPDF1.5, at $\mu^2 = 3.0\text{GeV}^2$, scaled but less



Normalization scaling factor k=0.91

- Good agreement, between HERAPDF 1.5 and all J/ψ data!

Plots from Andreas Weiden (summer student)

- Should we start to use the J/ψ data in PDF fits?

- What are the theoretical assumptions, and difficulties doing that?
  - What is the correct scale?
  - Should one also fit the normalization or only the W-dependance?
  - How does a gluon from J/ψ dWhat are the assumptions?
  - J/ψ cross sections are sensitive to 2 gluons, with 2 different x-values …
  - One has to integrate over t to get σ, and assumes a W-dependance on b.

    → Is the corresponding systematic error relevant?
  - Whats about the LHCb data? They measure in principle η and not W...

- Special talk of Stephen Jones, collaborator of Alan Martin, Mikhail Ryskin, Thomas Teubner.

backup

Leading logarithmic order theory

Differential cross-section

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

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

where Γ_{ee} is the electronic width of the J/ψ, $M_{J/\psi}$ its mass and:

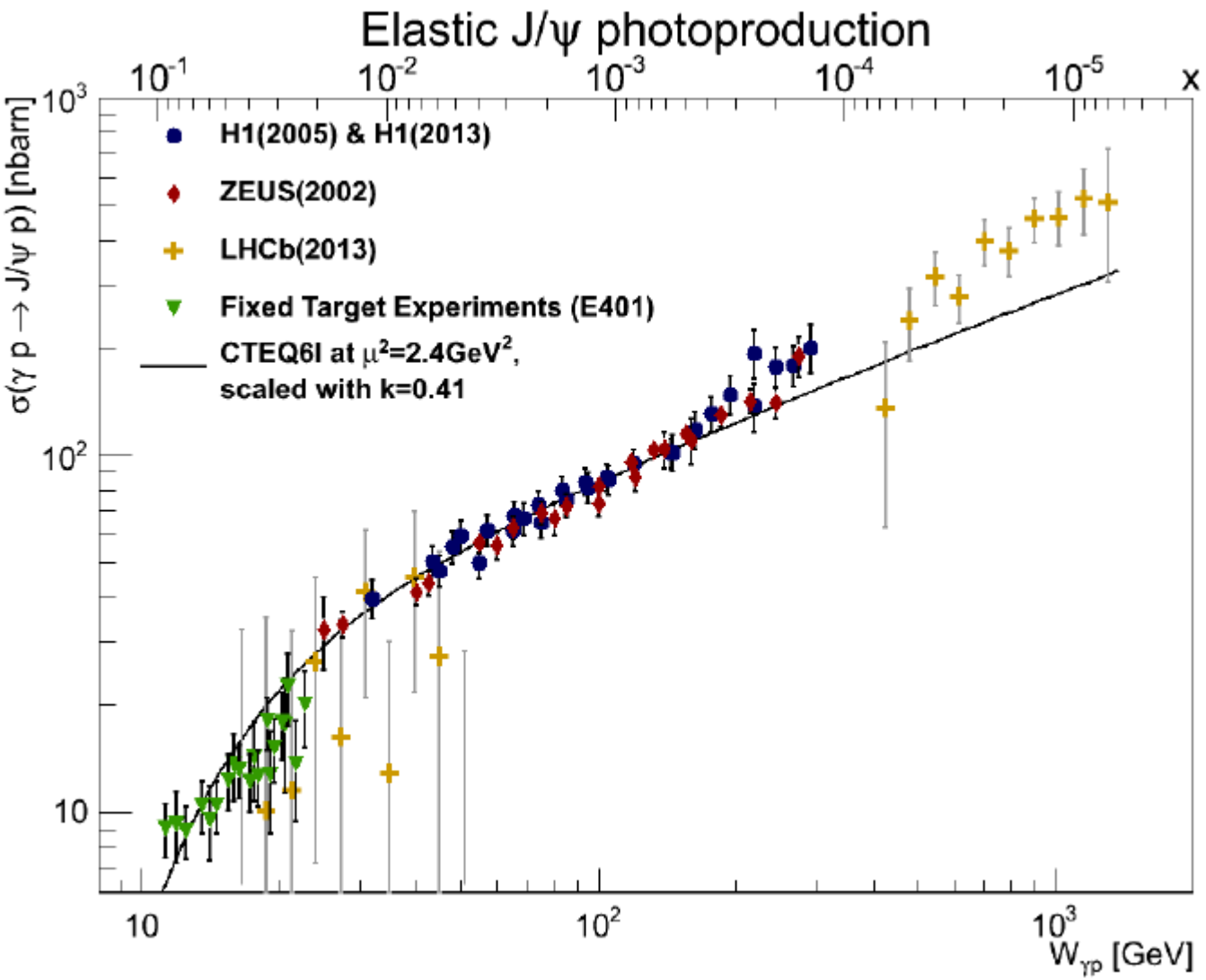
$$\bar{Q}^2 = (Q^2 + M_{J/\psi}^2)/4, \quad x = (Q^2 + M_{J/\psi}^2)/(W^2 + Q^2).$$

Q^2 is the virtuality of the photon and $W_{\gamma p}$ is the center-of-mass energy. The t integration is carried out assuming $\sigma \propto \exp(-Bt)$, with B the slope parameter:

$$B(W) = (4.9 + 0.24 \ln(W/90\mathrm{GeV}))\,\mathrm{GeV}^{-2}$$

Slide from
Andreas Weiden

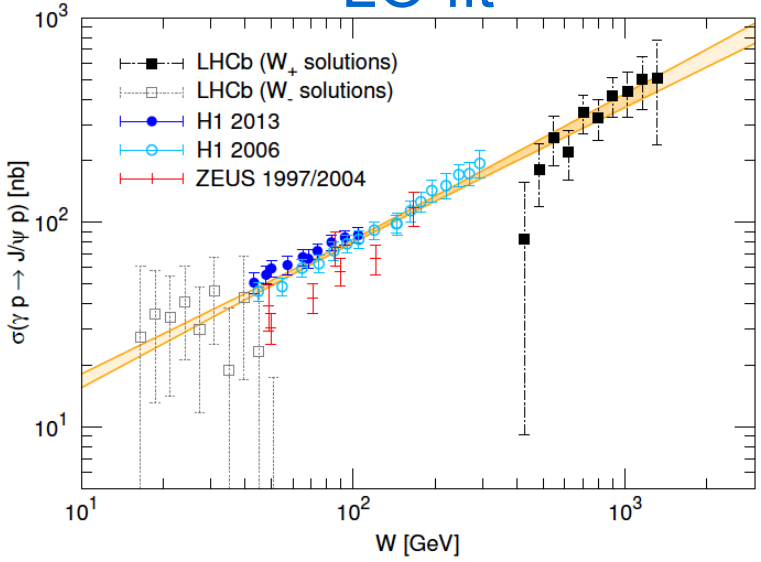
Comparison to CTEQ6l, at $\mu^2 = 2.4\text{GeV}^2$, scaled



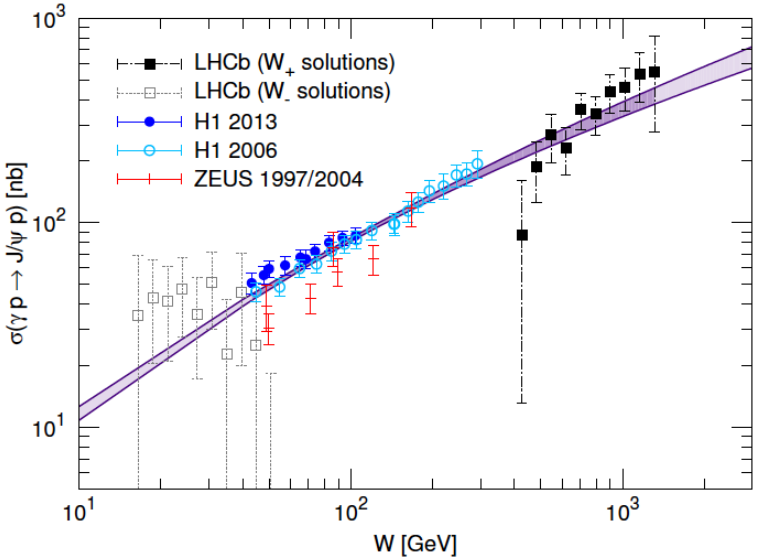
Plots from Andreas Weiden (summer student)

Comparison to new fits based on QCD calculations

LO fit

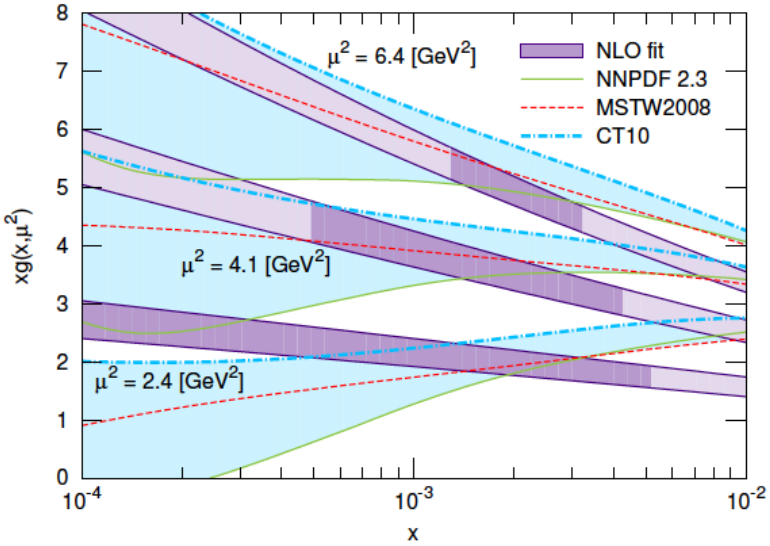


NLO fit



- LO and NLO describe the data well.

- NLO gluon pdf compared to recent gluon pdfs from global analyses:
  → below x≈10^{-3} the uncertainties on the pdfs from the global analyses are large, and could be reduced using J/ψ data .

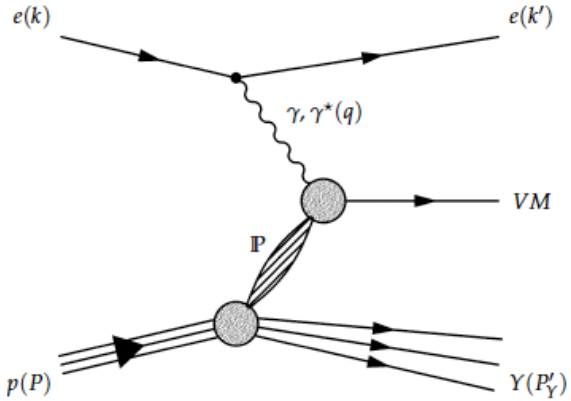


S.P. Jones, A.D. Martin, M. Ryskin and T. Teubner, arXiv:1307.7099

Theoretical models for diffractive Vector Meson production

Regge Approach

- "soft region"



- Soft Pomeron IP exchange

$$\alpha_P(t) = \alpha_0 + \alpha' t$$

$$\alpha_0 = 1.08, \alpha' = 0.25\, GeV^{-2} \quad \text{(DL)}$$

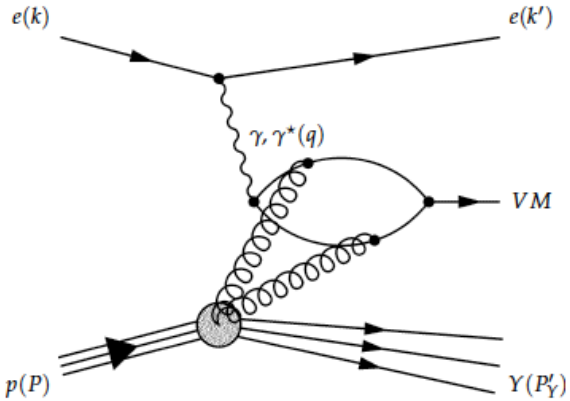
$$\frac{d\sigma}{dt} \propto e^{bt} \left(\frac{W_{\gamma p}}{W_0} \right)^{\delta} \qquad \delta = 4(\alpha_0 - 1)$$

$$b = b_0 + 4\alpha' \ln\left(\frac{W_{\gamma p}}{W_0} \right)$$

- Weak energy dependence of $\sigma \propto W_{\gamma p}^{\delta}$

pQCD Approach

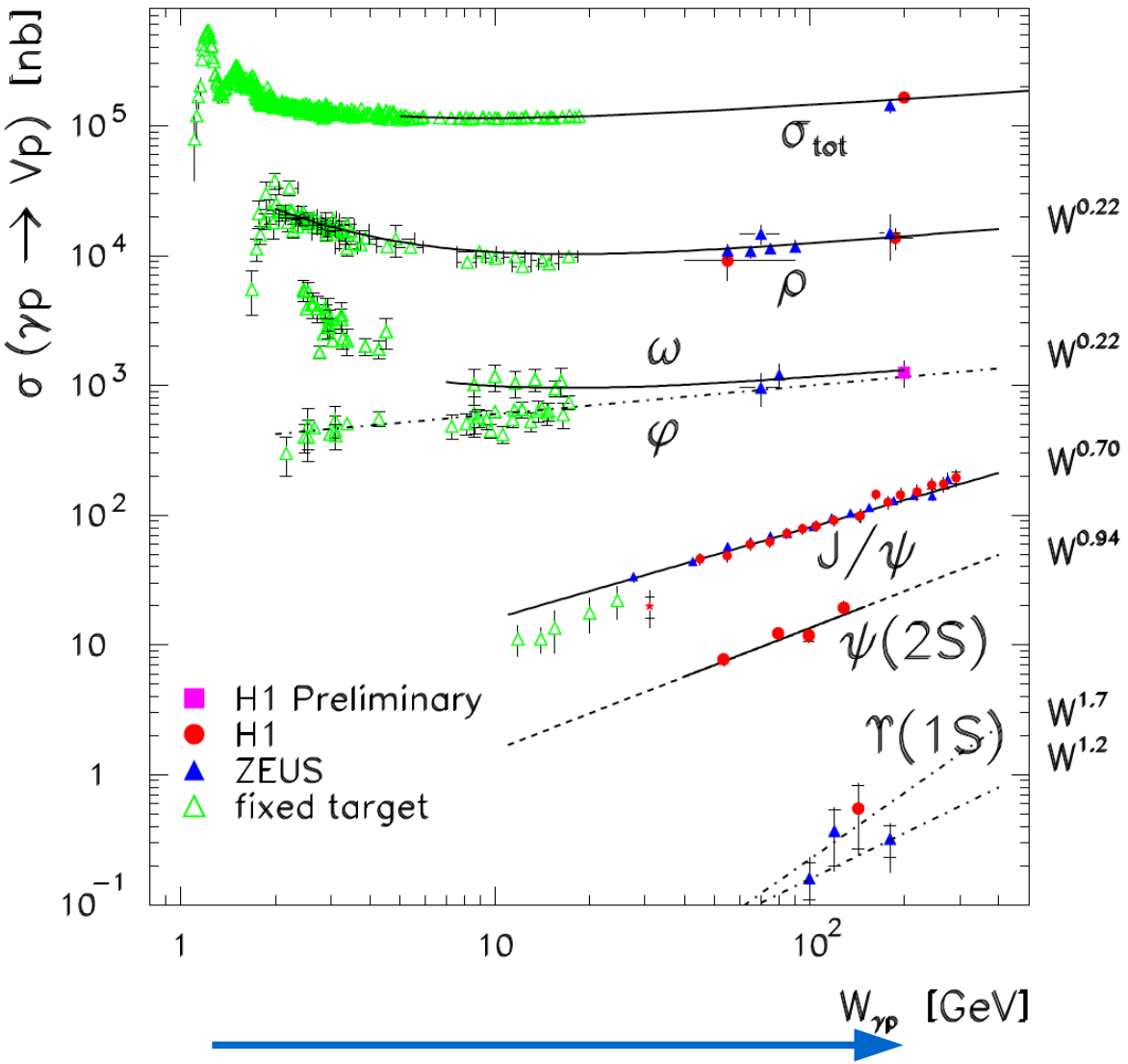
- "hard region", scales for pQCD: Q^2, M_V, t



- Exchange of ≥ 2 gluons:
  1. Virtual photon fluctuates into qq pair
  2. which interacts with the proton trough the exchange of a two gluon-ladder
  3. qq recombines into VM.
- VM cross section has sensitivity to squared gluon density in proton:

$$\begin{cases} \sigma \propto [x\, g(x, \mu^2)]^2 \\ x = \mu^2 / W^2 \\ \mu^2 \propto (Q^2 + M_V^2) \end{cases}$$

$W_{\gamma p}$ dependance of Elastic Vector Meson Photoproduction

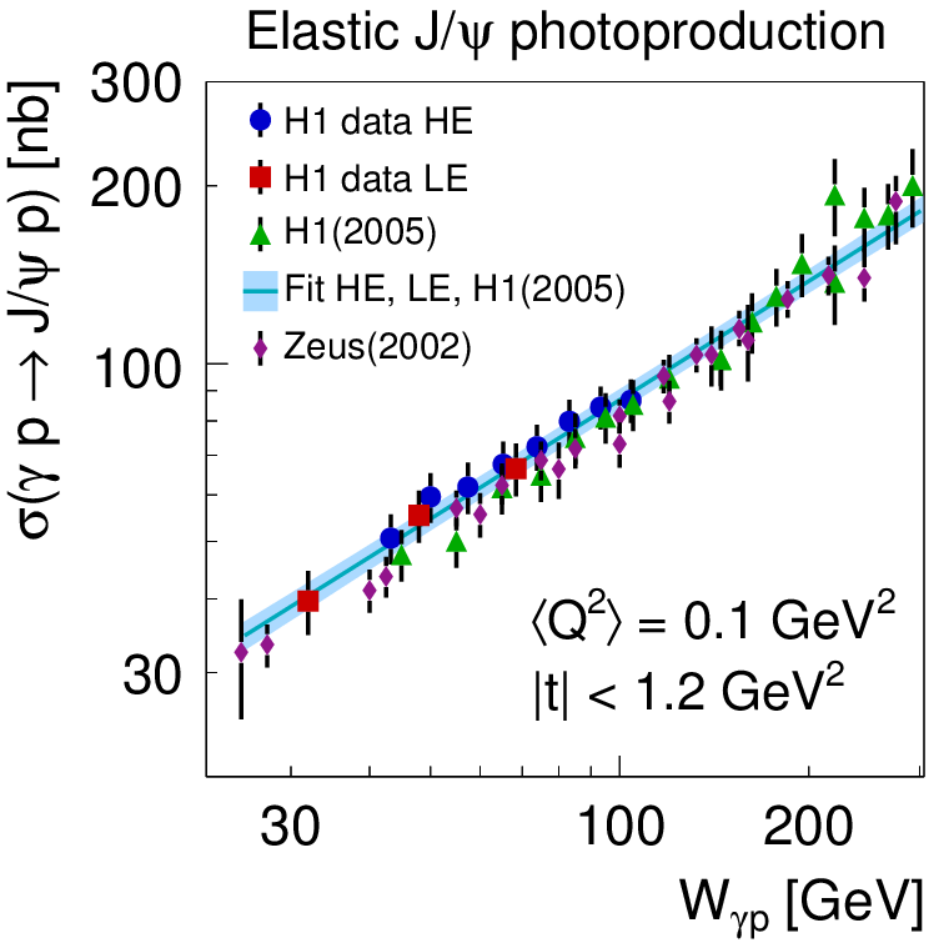


$W_{\gamma p} \propto 1 / \sqrt{x}$

With increase of VM mass (M_V) process gets harder:

- Consistent with soft models, $\delta \sim 0.2$
- Cross section rises faster, $\delta > 0.2$
  → "hard regime"
  → sensitivity to gluon density in proton:
  $\sigma \propto [x\, g(x,M_V)]^2$

Comparison to previous H1 and ZEUS data



- Large overlap with previous H1 and ZEUS measurements.
- Similar precision in the range $30 < W_{\gamma p} < 110$ GeV. (Normalization uncertainties of ~5% are not shown).
- Good agreement of HERA measurements.