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on behalf of the

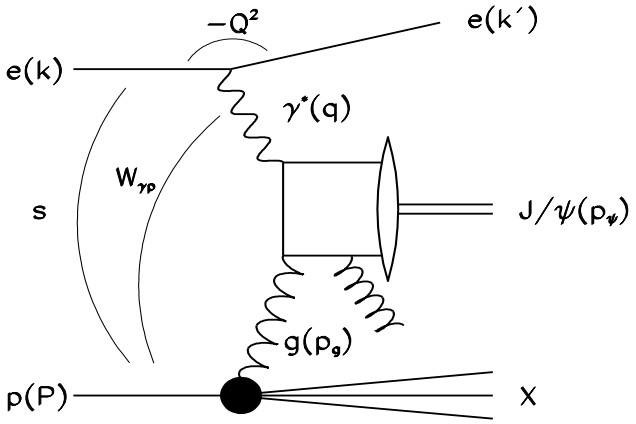
ZEUS Collaboration

Inelastic J/ψ production at HERA

Outline:

- Introduction
- J/ψ production mechanisms
- Inelastic J/ψ photoproduction
- Inelastic J/ψ electroproduction
- Conclusions & Outlook

Introduction- I



kinematical variables:

$Q^2 = -q^2 = -(k-k')^2$

$s = (P+k)^2$

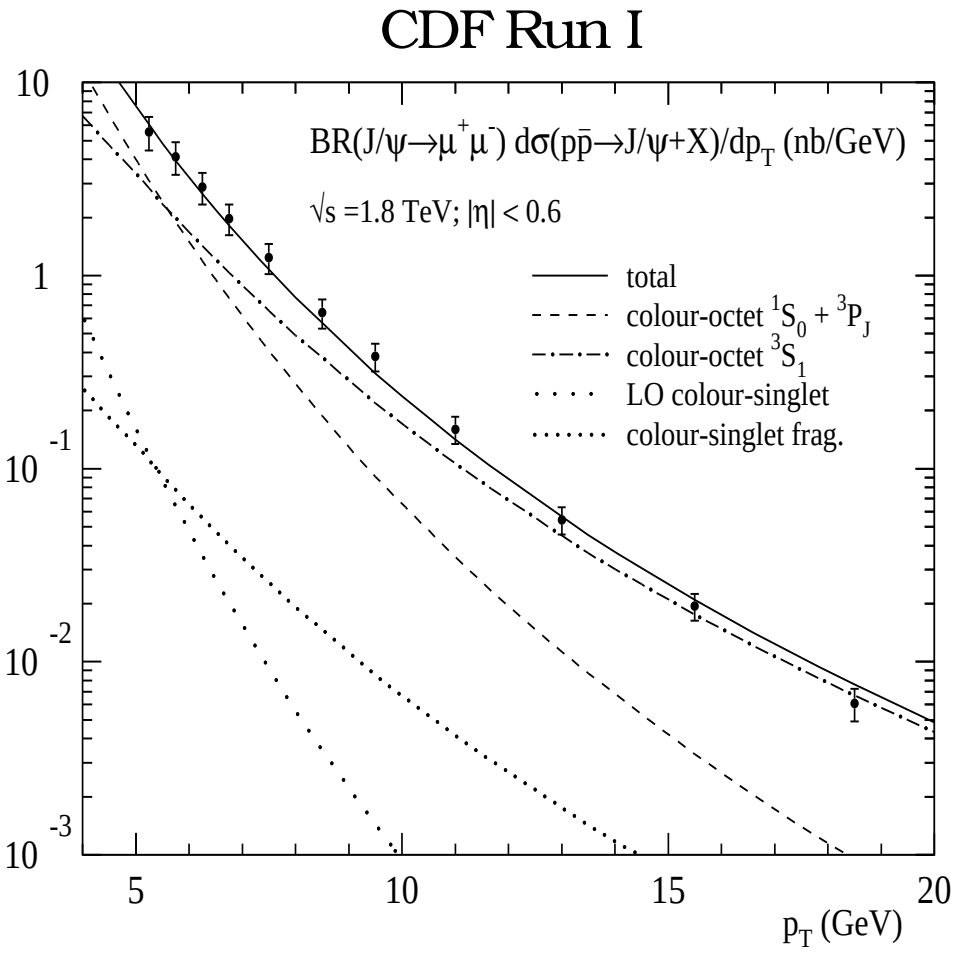
$W^2 = (\gamma + P)^2$

$z = p_{J/\psi} \cdot P / q \cdot P$

$= E^*_{J/\psi} / E^*_{\gamma}$ in the proton rest frame

- **photoproduction** ($Q^2 <$ **1 GeV**^{2}):
  scattered *e* not seen in the main detector
- **electroproduction (2 <** $Q^2 <$ **100 GeV**^{2}**):**
  scattered *e* detected in calorimeter
- J/ψ **detected through:**
  $\mu^+\mu^-$, e^+e^- **decay modes**

Introduction- II



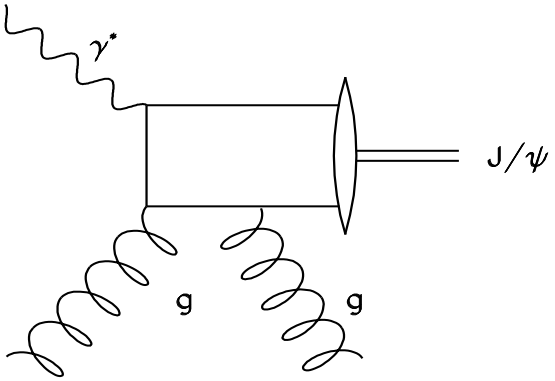
How is the quarkonium produced?

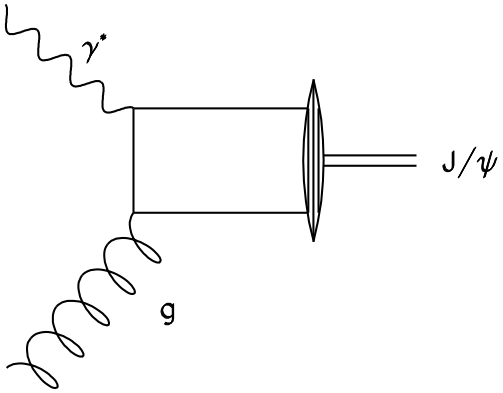
Colour Singlet Model (CSM)
orders of magnitude too low

Possible solution:
non- relativistic QCD (NRQCD)

Production mechanisms- I

direct photon gluon fusion $z \geq 0.2$





Colour Singlet Model

$c\bar{c}$ must have J/ψ quantum numbers

one parameter fixed from $\Gamma_{\psi \to l^+ l^-}$

CSM

non- relativistic QCD

$c\bar{c}$ also in colour octet state

additional free parameters

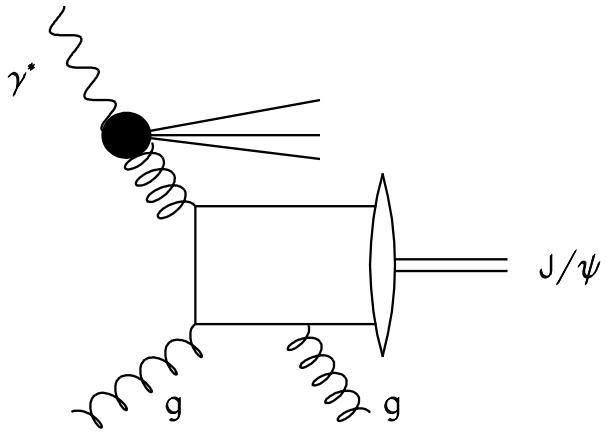
long distance matrix elements LDMEs

LDMEs not calculable → from experiment

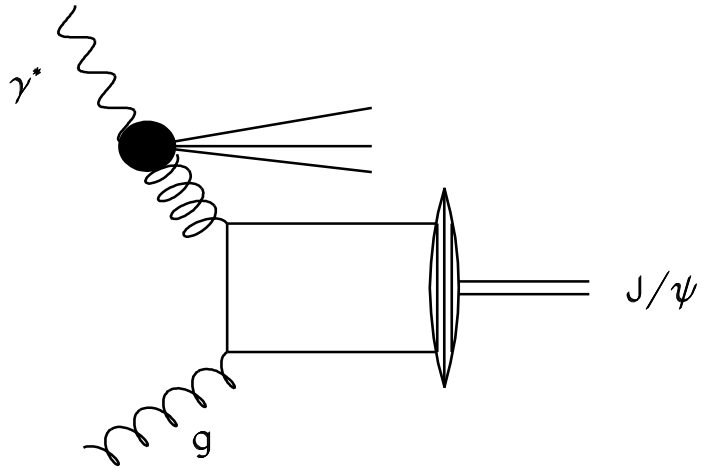
CS + CO

Production mechanisms- II

resolved photon processes (gluon- gluon fusion): $z \lesssim 0.2$
suppressed with increasing Q^2

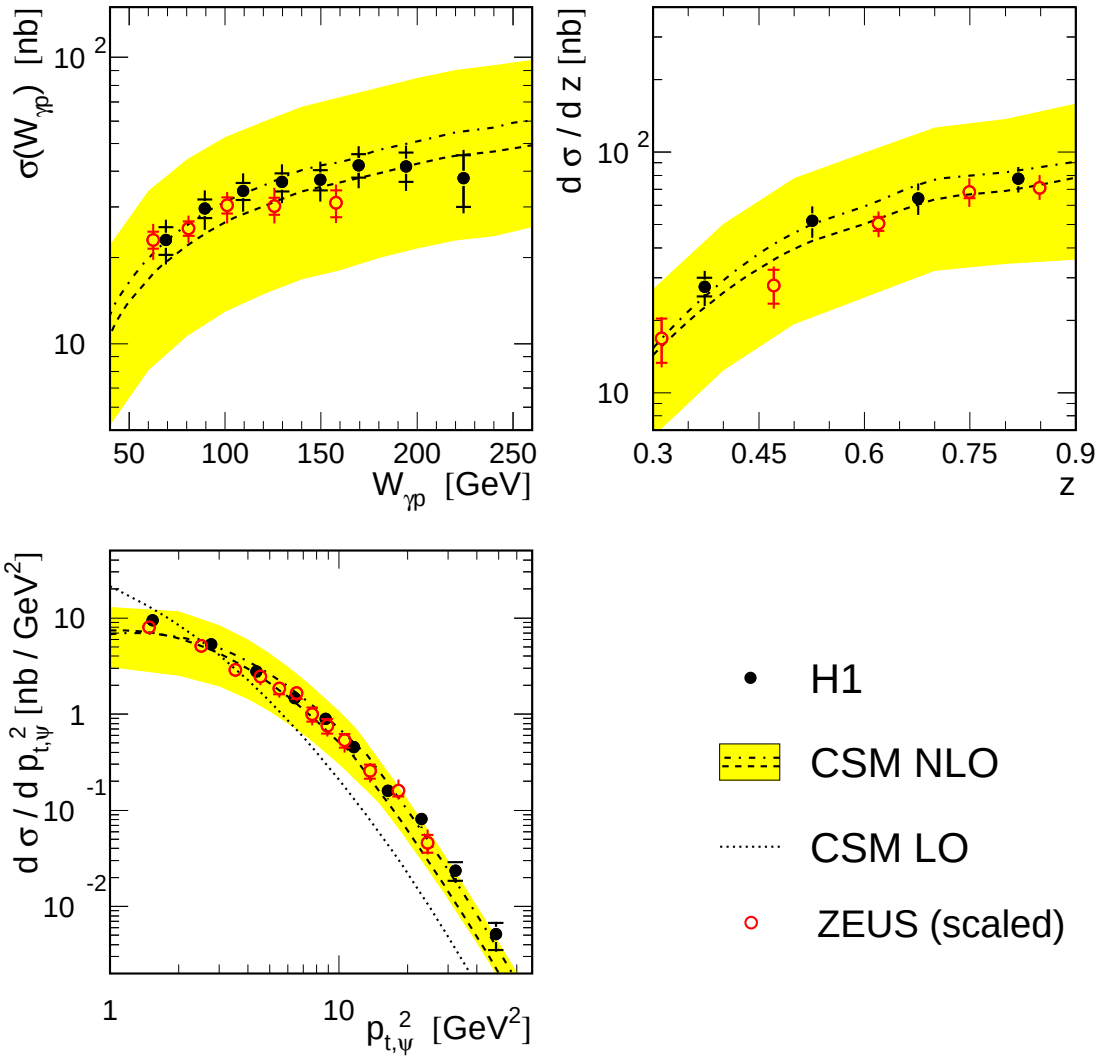


Colour Singlet Model



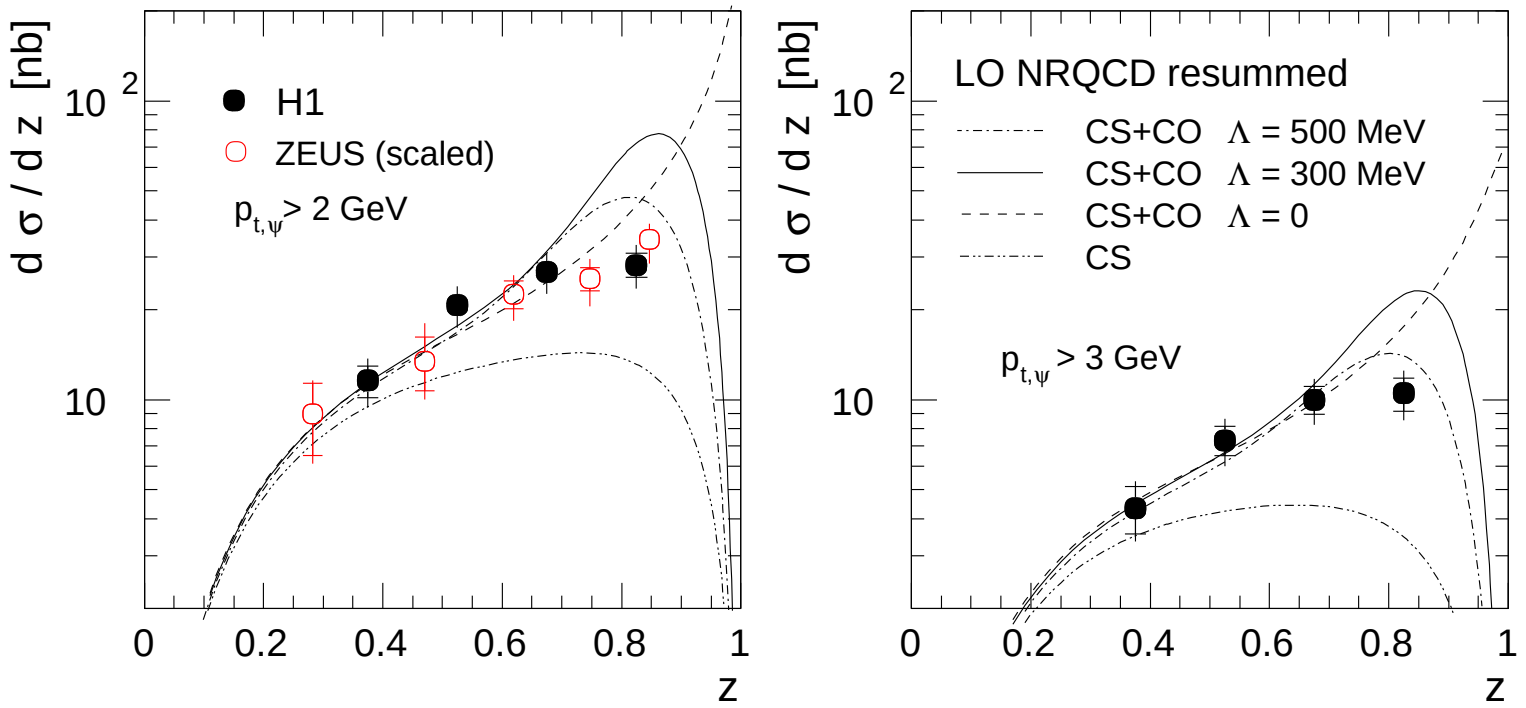
non- relativistic QCD

Photoproduction: comparison with CSM NLO



- **Agreement between H1 and ZEUS data**
- **full NLO calculation of the direct γ gluon fusion in the CSM (M. Kraemer)**
- **within the large theoretical uncertainties, the prediction is in agreement with the data, both in shape and in normalization**

Photoproduction: comparison with NRQCD(LO)



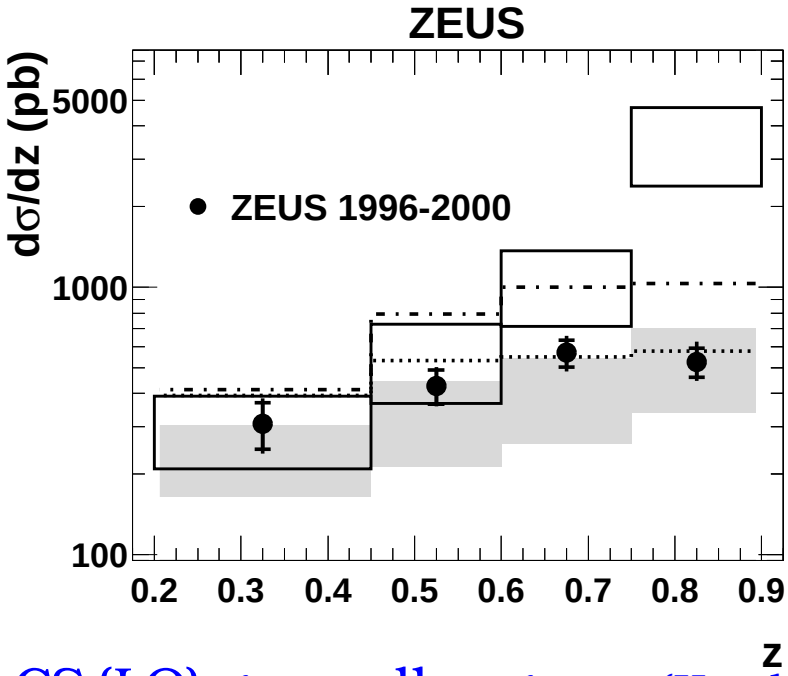
- LO NRQCD calculation resumming soft contribution at high z (M. Beneke, G.A. Schuler and S. Wolf)
- Λ: Energy loss of J/ψ due to soft gluon radiation

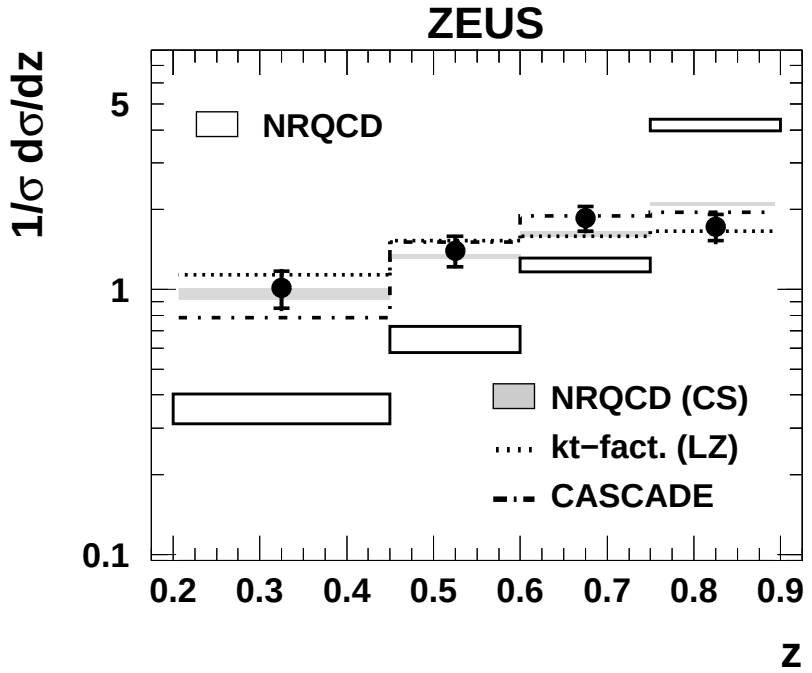
$\Rightarrow$ **resummation reduces discrepancy at high z**

Electroproduction

- Inelastic J/ψ production at large Q^2 has a smaller cross section than in photoproduction but presents several interesting aspects.
- The contribution from the CO model is expected to be more significant.
- Both CO and the CS predictions should be more accurate due to the higher scale in the interaction.
- Backgrounds from diffractive processes are reduced at high Q^2.

Electroproduction: $d\sigma/dz$ and $1/\sigma\ d\sigma/dz$





- CS (LO) generally agrees (Kniehl and Zwirner)
- CS + CO: too high at high z, resummation needed (such as in γp regime) (Kniehl and Zwirner)
- k_t - factorisation (CS) gives good description (Lipatov and Zotov)
- CASCADE MC: absolute prediction overshoots the data; shape reasonable

ZEUS kinematic range:

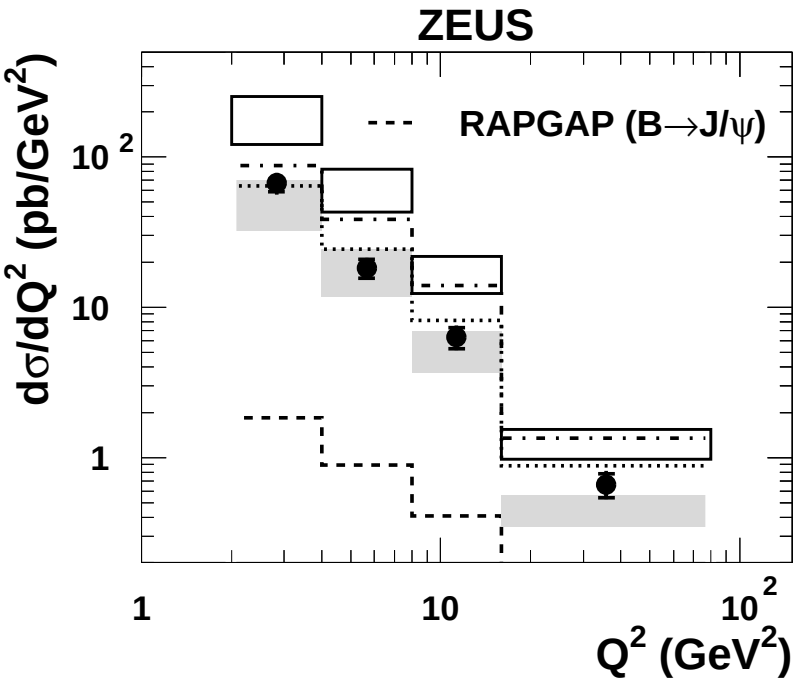
$2 < Q^2 < 80\ \text{GeV}^2$

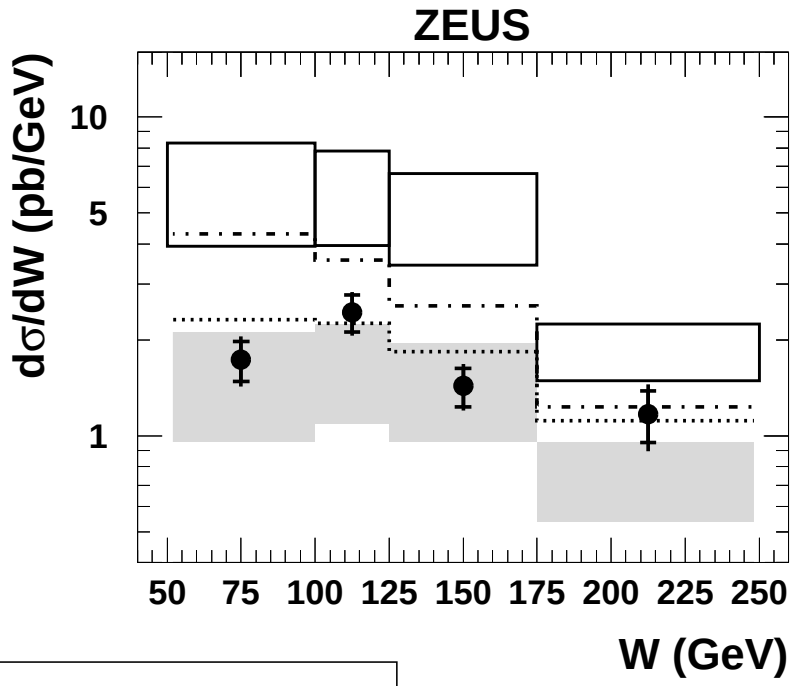
$50 < W < 250\ \text{GeV}$

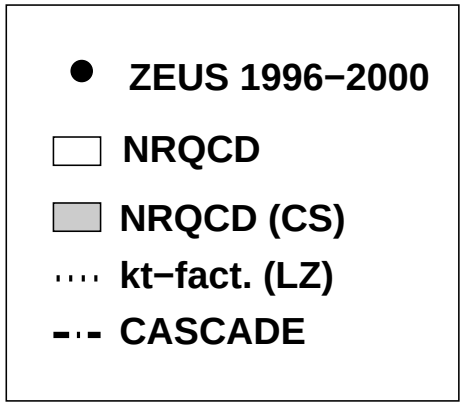
$0.2 < z < 0.9$

$-1.6 < Y_{\text{lab}} < 1.3$

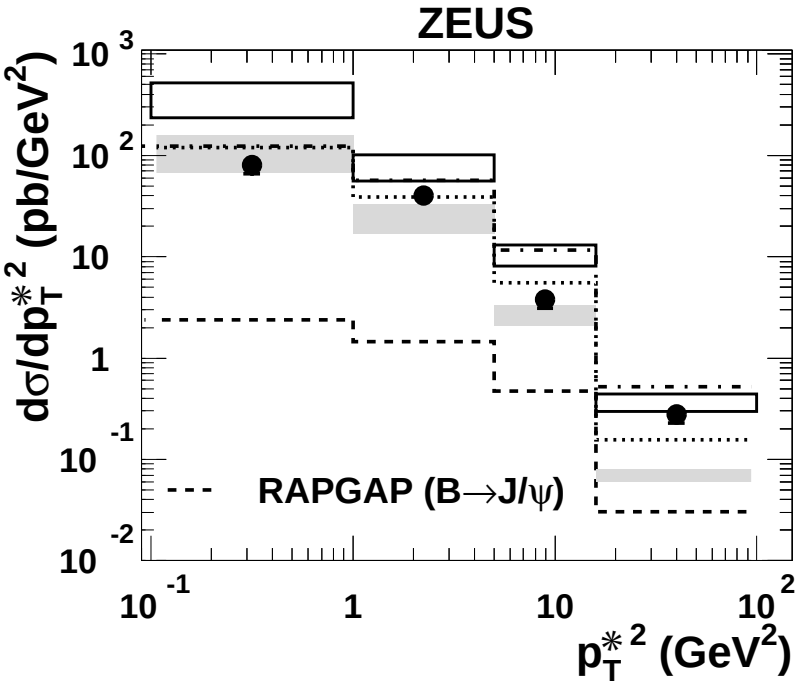
Electroproduction: $d\sigma/dQ^2$ and $d\sigma/dW$

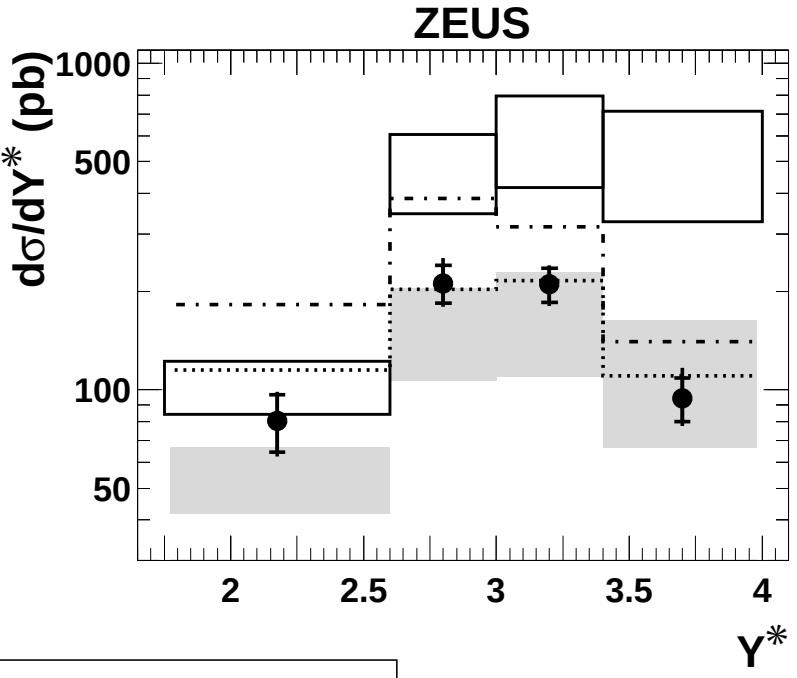


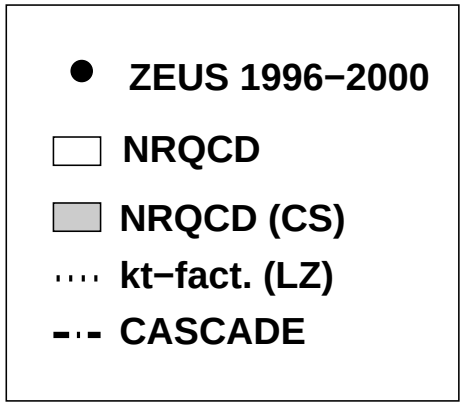




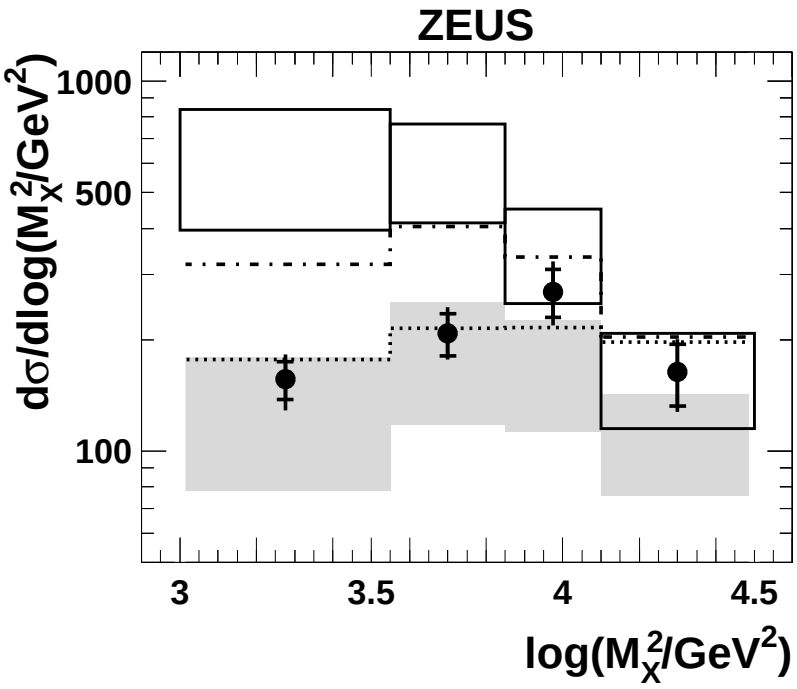
Electroproduction: $d\sigma/dp^{*2}_T$ and $d\sigma/dY^*$ in $\gamma^* p$

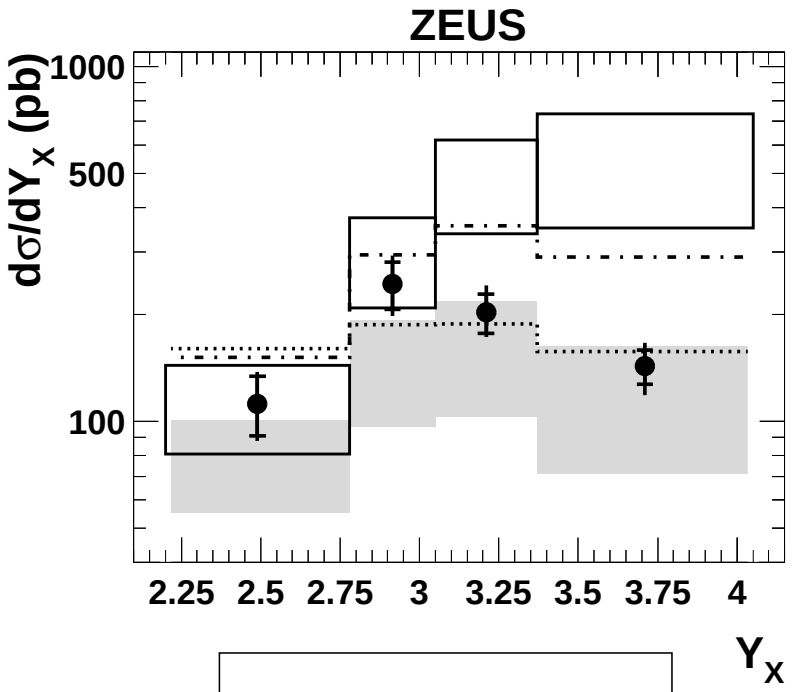


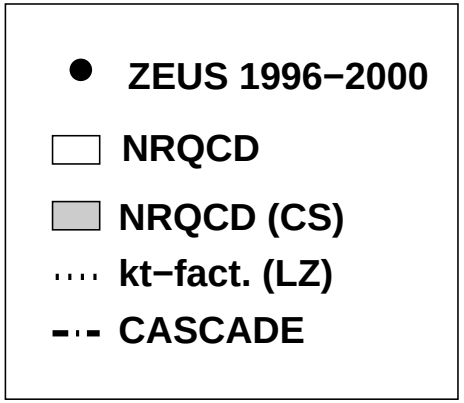




Electroproduction: $d\sigma/d\log(M^2_X)$ and $d\sigma/dY_X$

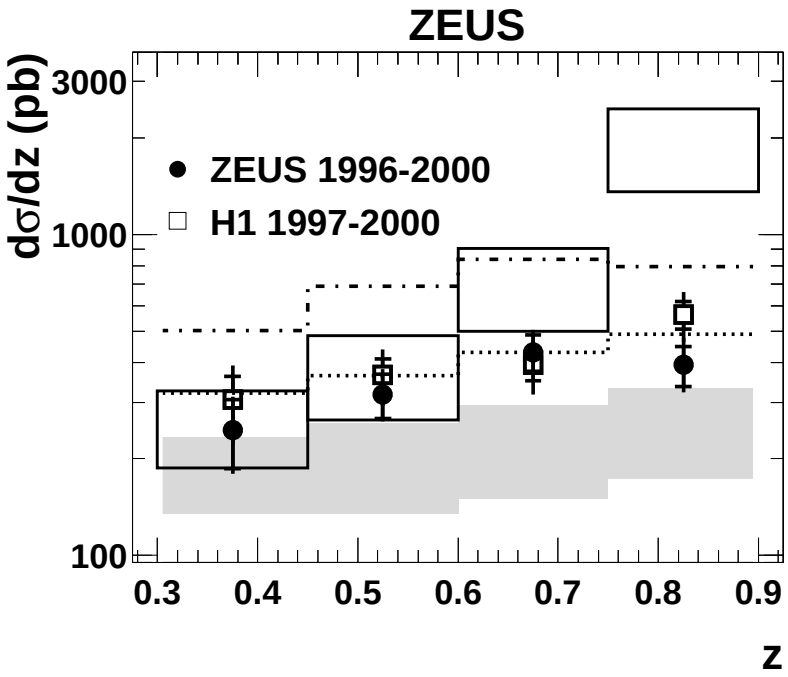


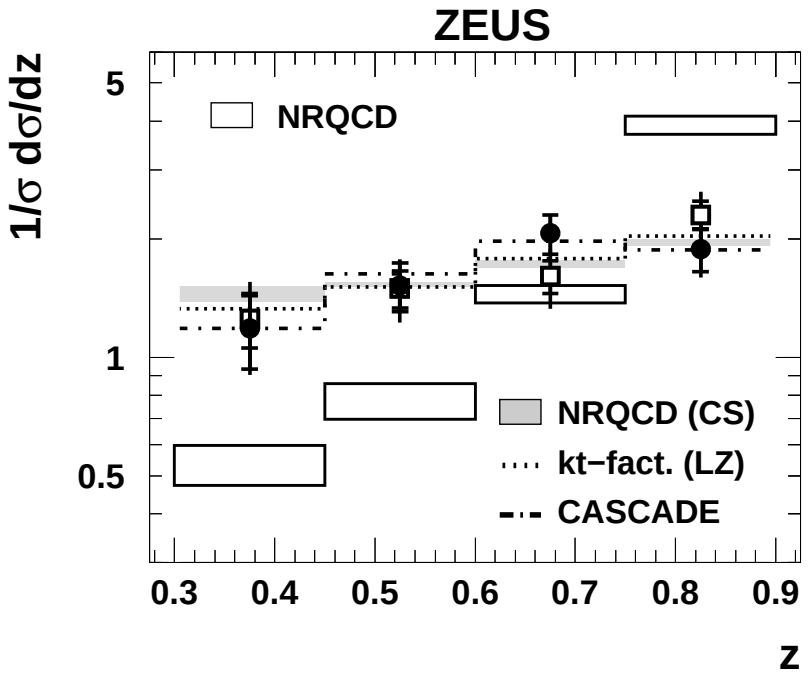




where M_X is the invariant mass of the hadronic final state and Y_X its rapidity

Comparison with H1: $d\sigma/dz$ and $1/\sigma\ d\sigma/dz$





H1 kinematic range:

$2 < Q^2 < 100\ \mathrm{GeV}^2$

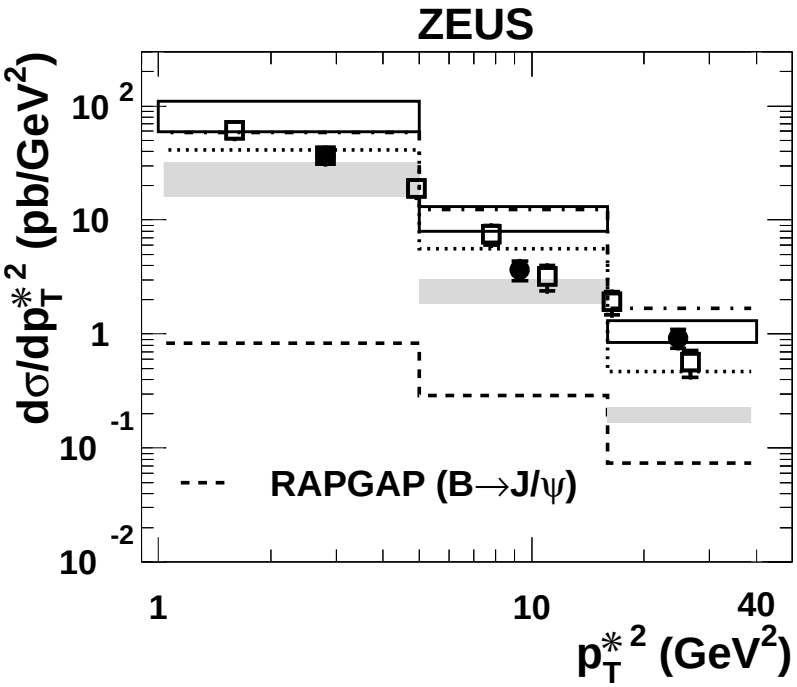
$50 < W < 225\ \mathrm{GeV}$

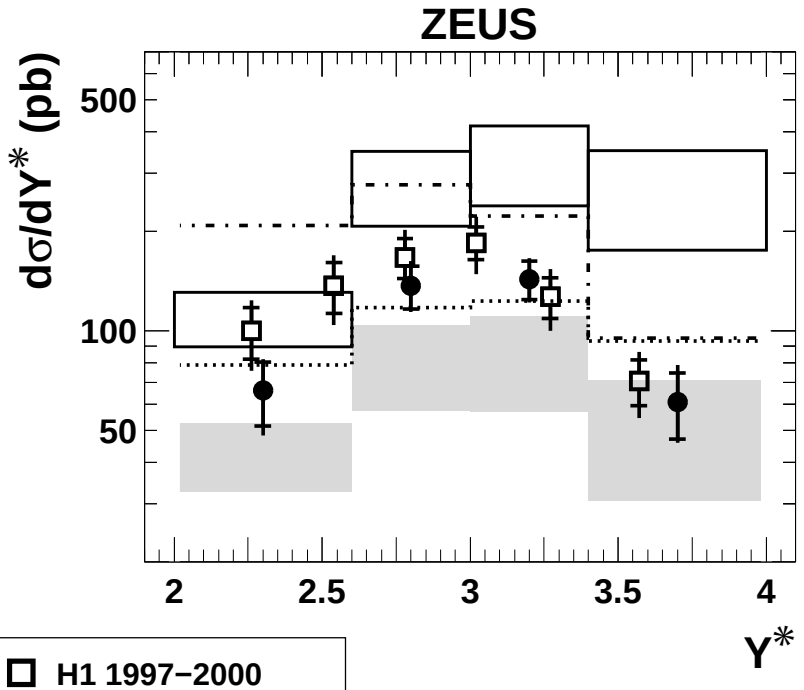
$0.3 < z < 0.9$

$p^{*2}_T > 1\mathrm{GeV}^2$

- **Agreement between H1 and ZEUS data**
- **CS underestimates the norm. but describes the shape**
- **CS+ CO too high at high z**
- **CS with kt- factorization agrees with the data**

Comparison with H1: $d\sigma/dp^{*2}_T$ and $d\sigma/dY^*$ in $\gamma^* p$





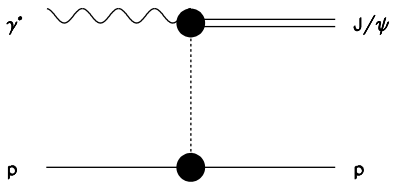
- CS underestimates the data at high p^{*2}_T
- CS+ CO too high
- CS with kt- factorization agrees with the data

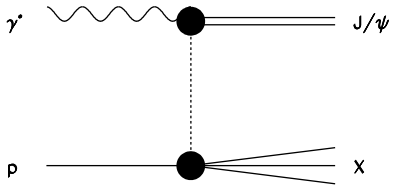
Conclusions and Outlook

- ZEUS and H1 have produced measurements of inelastic J/ψ in DIS using complete data sample available in HERA I. The measurements are in agreement between them.
- Comparing with existing theoretical models:
  - CS (LO) generally agrees; but after applying $p^{*2}_T > 1\text{GeV}^2$ cut, normalization seems too low and discrepancies at high p^{*2}_T
  - CS+ CO too high, wrong z dependence.
  - CS with k_T- factorization generally agrees with the data.
  - CASCADE is above data, shapes of distributions reasonable described.
- Improvement in data statistics possible with HERA II data.
- *Calculations with higher order corrections and soft gluon emission treatment are absolutely needed.*

Production mechanisms- III (background)

- **diffraction (**subtracted in ZEUS data (≈6%), not subtracted in H1 data (<2%))





suppressed by cuts on:
- z ($z < 0.9$)
- $p^*_{T,\psi}$ ($\approx p_{T,\psi}$ in γp)
- additional activity in the detector

elastic diffraction $z = 1$

proton dissociation $z \approx 1$

- **decay of diffractively or inelastically produced ψ' mesons**: $\psi' \rightarrow J/\psi\pi\pi$; not subtracted in data!
- **decay of χ_c mesons**: $\chi_c \rightarrow J/\psi\ \gamma$ (low z); not subtracted in data!
- **decay of B mesons**: $B \rightarrow J/\psi\ X$ (low z, high $p_{T,\psi}$); not subtracted in data!