Exclusive Production of J/ψ Mesons in DIS at HERA

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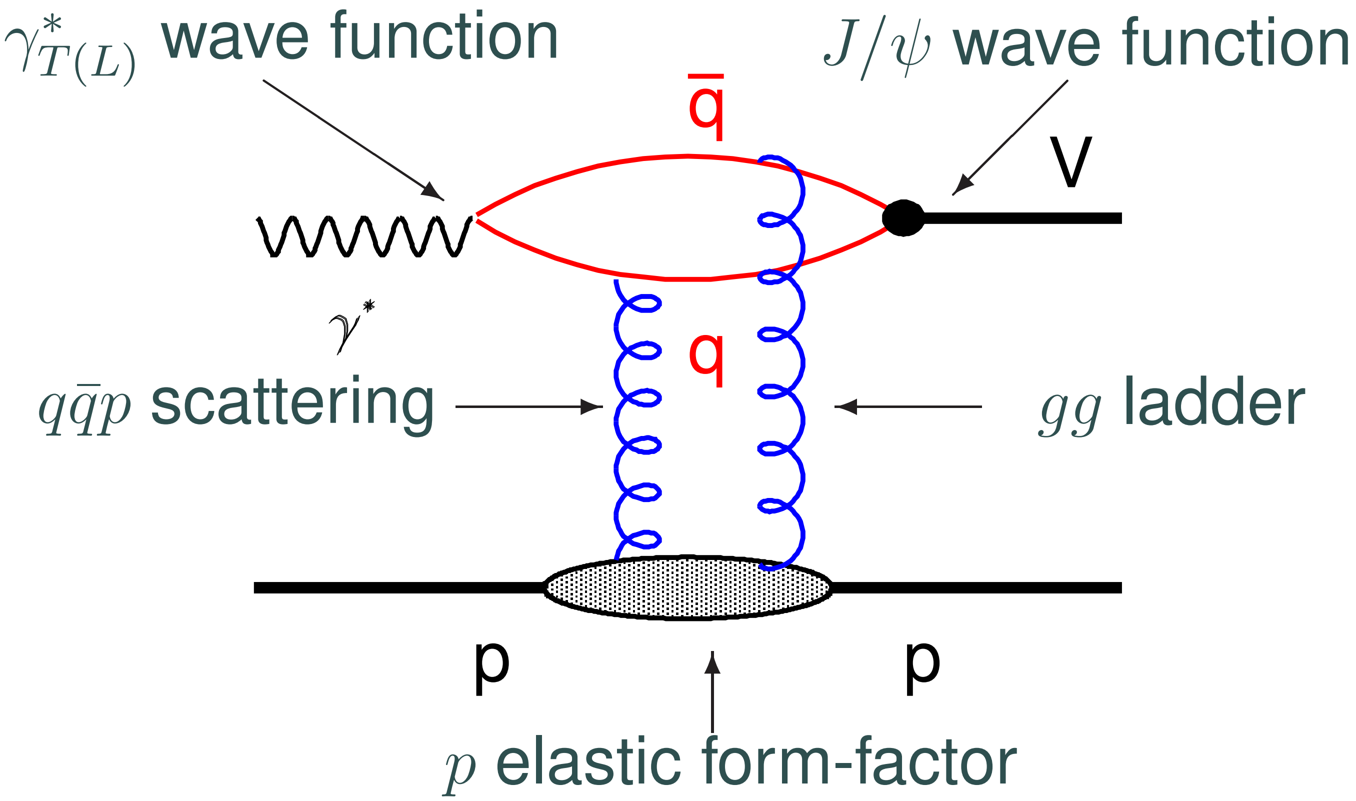
EXCLUSIVE J/ψ MESON IN $\gamma^* p$

Aim is understand J/ψ production in QCD



$\Rightarrow$ understand dynamics of high energy scattering in QCD

- test pQCD in transition regime soft-hard
- measure non-perturbative quantities (generalised) pdfs

MOTIVATION

- Exclusive VM production calculable in pQCD
- NLO calculation available for J/ψ PHP
- Strong sensitivity to gluons in proton
- $\sigma_L \simeq \frac{\alpha_S^2}{Q^6}|xG(x,Q^2)|^2 \Rightarrow \sigma_L \propto \frac{\alpha_S^2}{Q^6}|H(x_1,x_2,t,Q^2)|^2$
- Generalised PDFs, sensitive to parton parton correlation in the proton
- t-dependence gives distributions of gluons in transverse plane (via Fourier transform) $\rightarrow$ correlate longitudinal and transverse degrees of freedom

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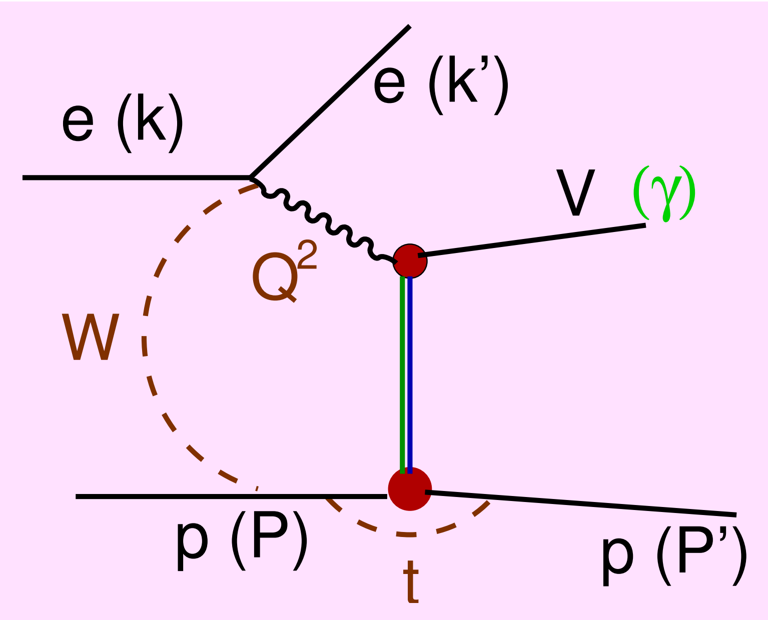
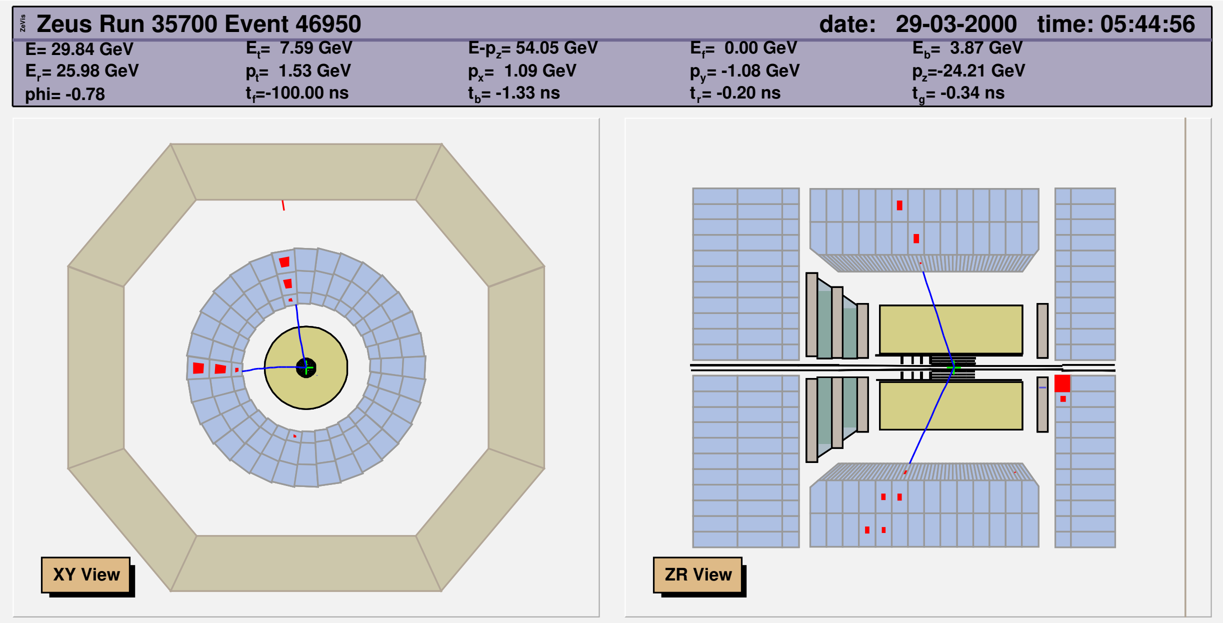
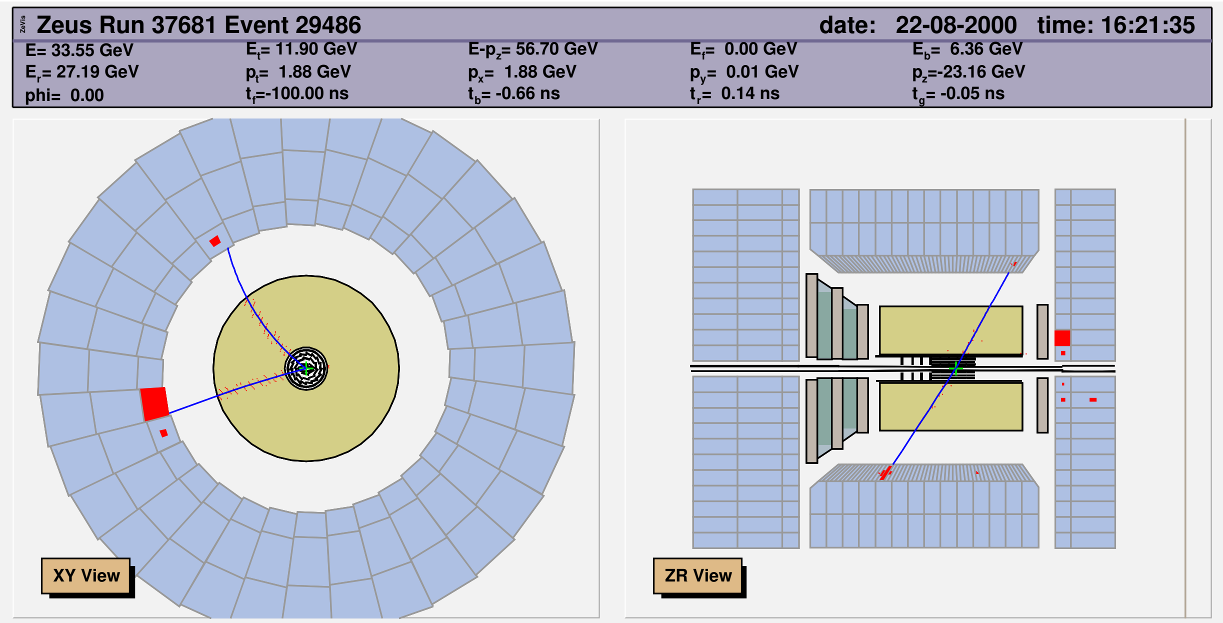
HERA regime: collisions of 27.5 GeV e with 920 GeV p

$0 < Q^2 < 100\ \mathrm{GeV}^2$ and $30 < W < 220\,\mathrm{GeV}$



- Q^2 - virtuality of exchanged γ^*
  $Q^2 = -q^2 = -(k - k')^2$
- W - $\gamma^* p$ centre of mass energy
  $W = (q + p)^2$
- 4-momentum transfer squared at the p vertex $t = (P - P')^2$
- x - Bjorken variable $x = \frac{Q^2}{P \cdot q} = \frac{Q^2}{Q^2 + W^2}$





Experimental signature

- scattered e reconstructed in CAL or beam pipe calorimeter
- scattered p undetected
- $J/\psi \rightarrow e^+e^-$, $\mu^+\mu^-$ (BR 6%)

  2 tracks reconstructed in central chamber

  associated to electrons or muons in CAL
- nothing else in the detector

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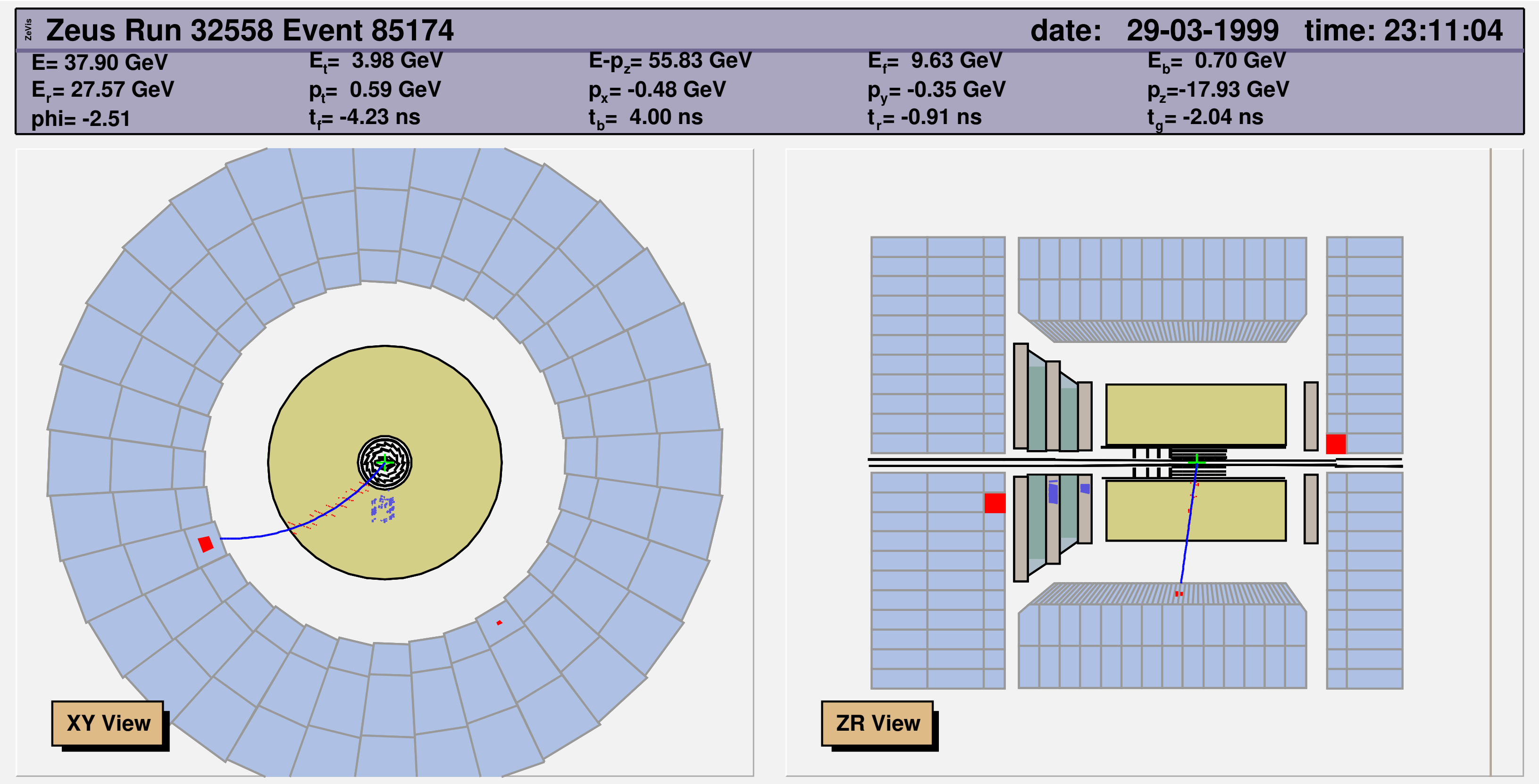
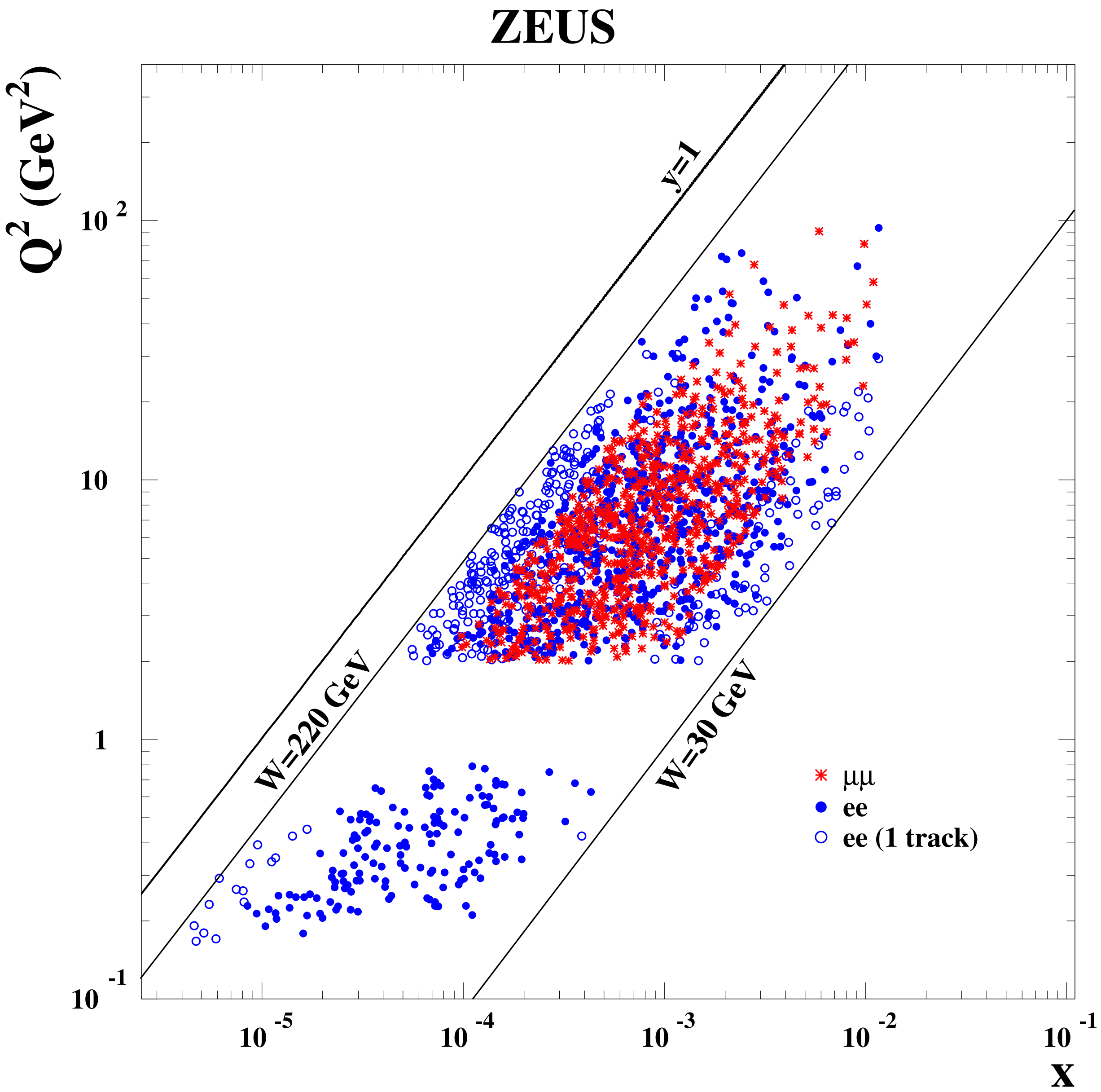


1 electron reconstructed in central chamber,

2^{nd} electron reconstructed in CAL, outside tracking acceptance



Kinematic range

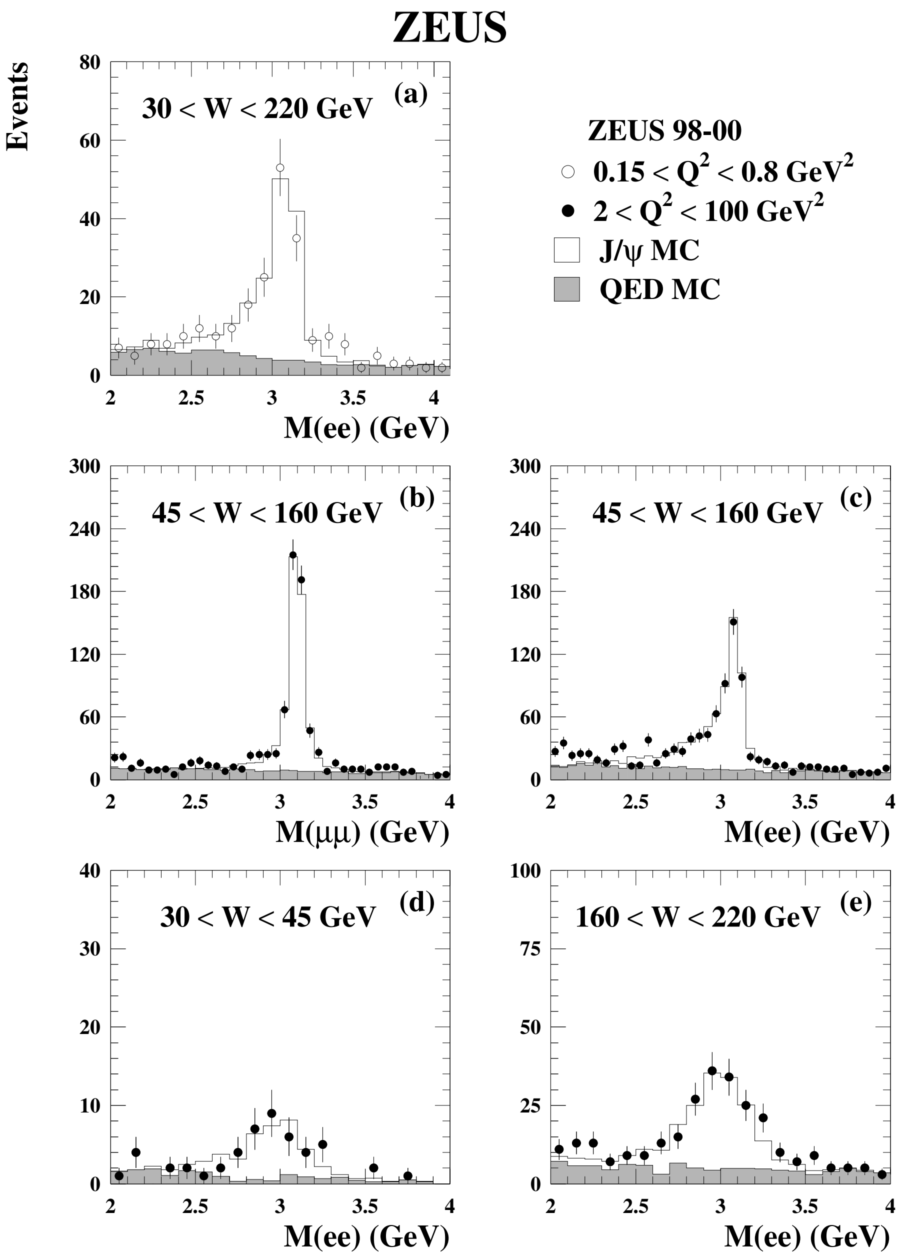
$0.15 < Q^2 < 0.8$ GeV^2(69 pb^{-1})

$2 < Q^2 < 100$ GeV^2 (83 pb^{-1})

$30 < W < 220$ GeV

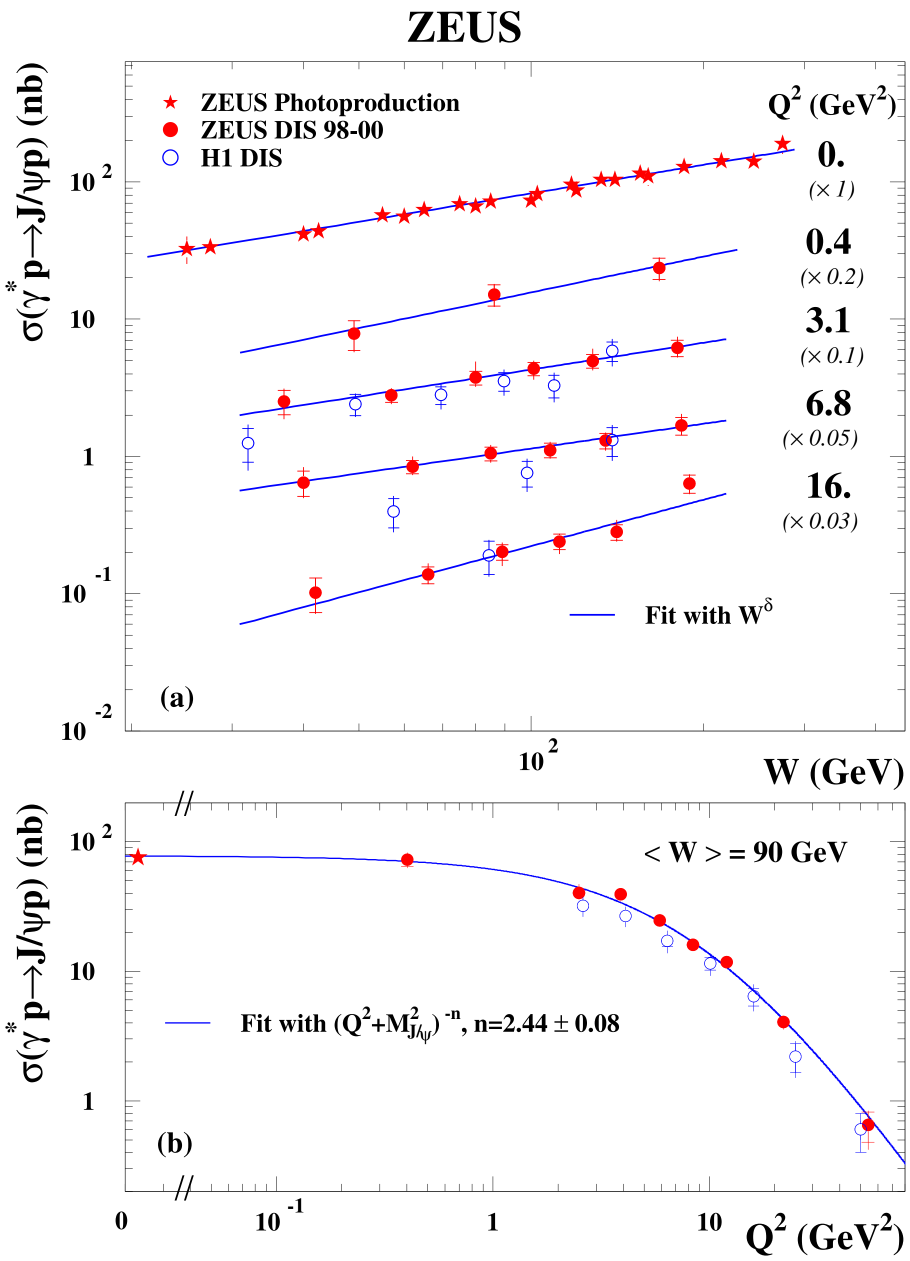
$-t < 1$ GeV^2

- one-track events allow to extend W range at low and high values



Extraction of signal

- events at low Q^2: 137 ee (16 with one track)
- events at high Q^2: 728 $\mu\mu$, 955 ee (275 with one track)
- non-resonant background 22% (14%) for $ee(\mu\mu)$
- background from pions 2.7% (0.8%) for $ee(\mu\mu)$
- background from $ep \to eJ/\psi Y$ $14.2 \pm 2.0(stat)^{+6.8}_{-3.6}(syst)$ independent from W and Q^2

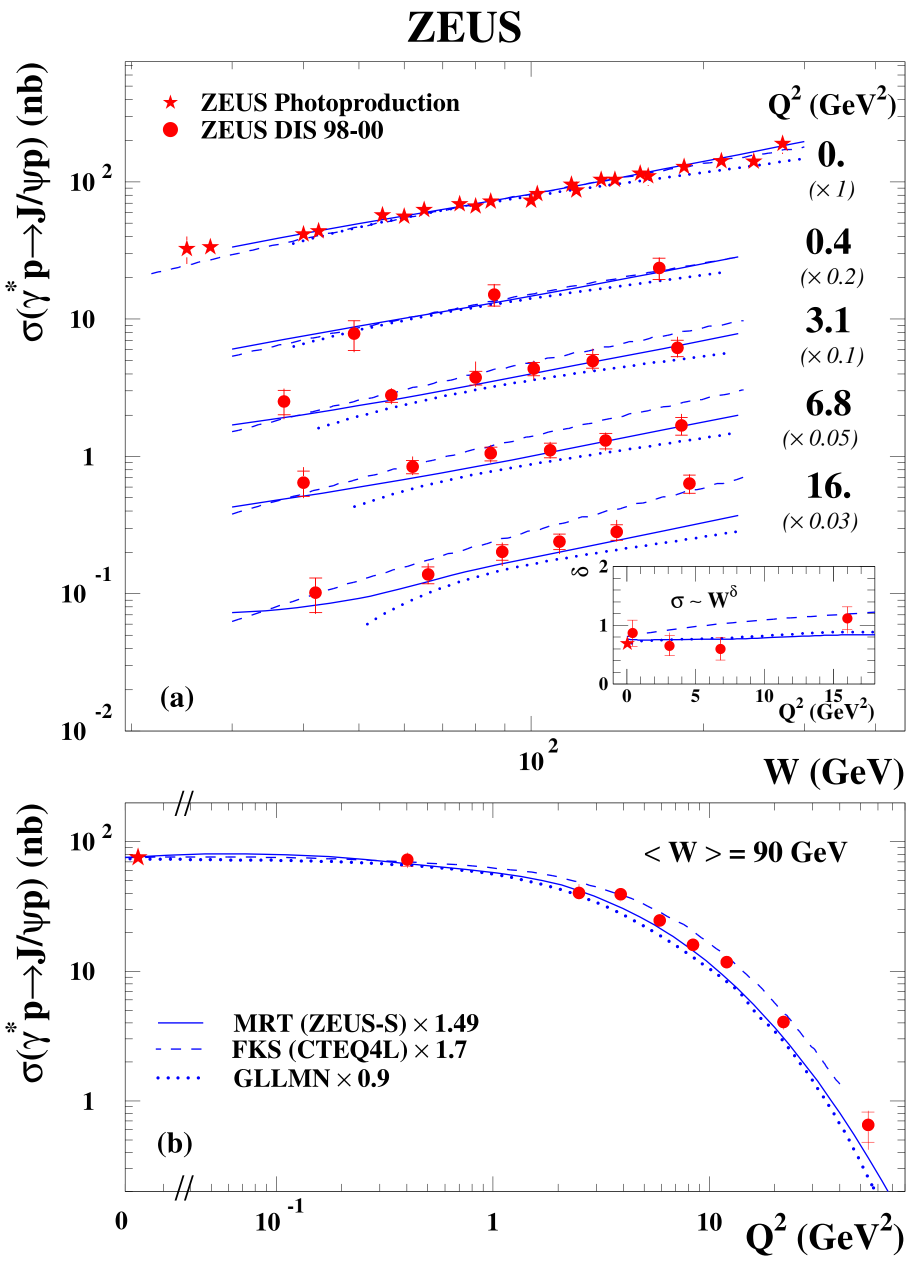


σ vs W in bins of Q^2

- $\sigma \propto W^\delta$
- no dependence of δ from Q^2

σ vs Q^2

- $\sigma \propto (Q^2 + M^2_{J/\psi})^{-n}$
- at $W = 90$ GeV n$= 2.44 \pm 0.08$

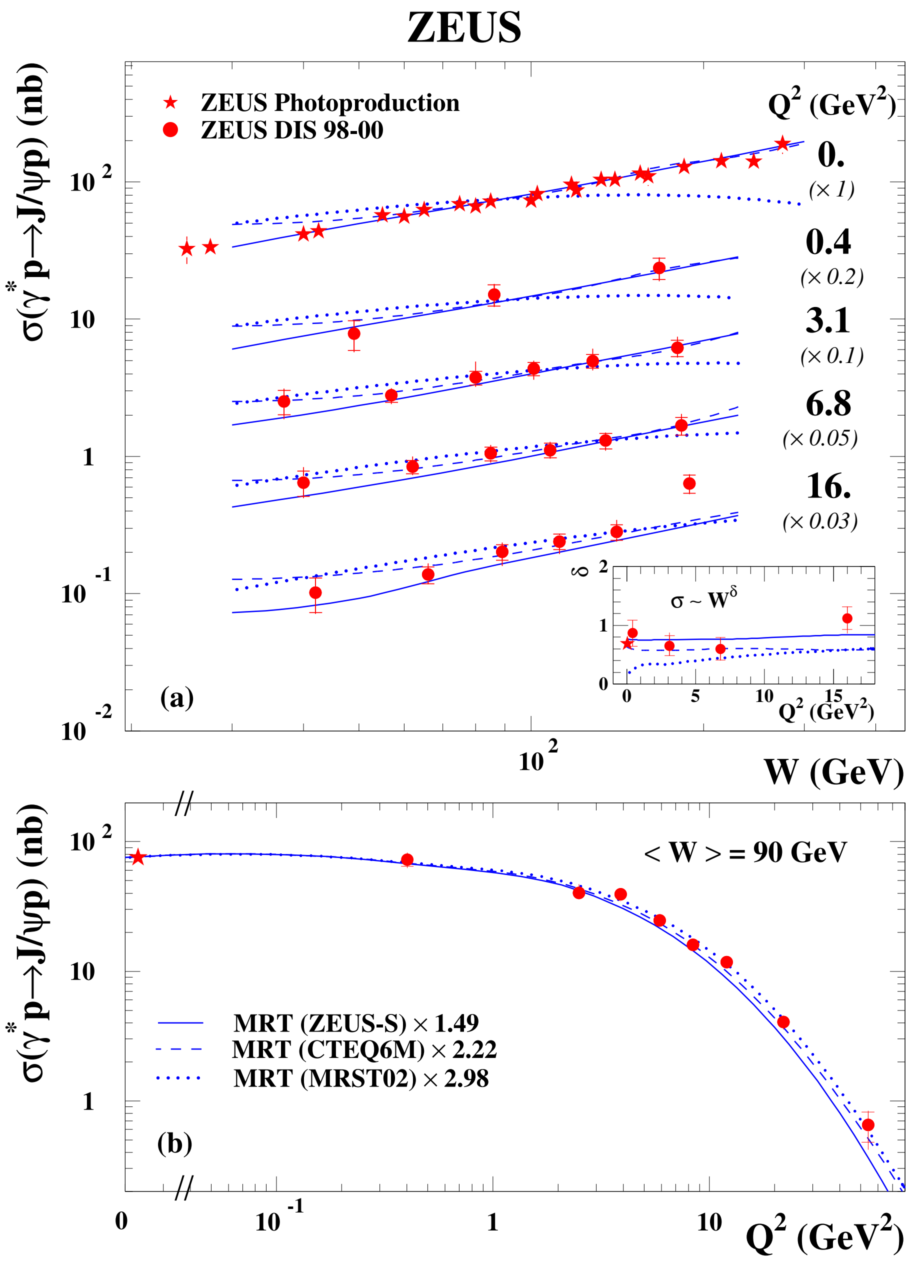


comparison with QCD models

models differ for

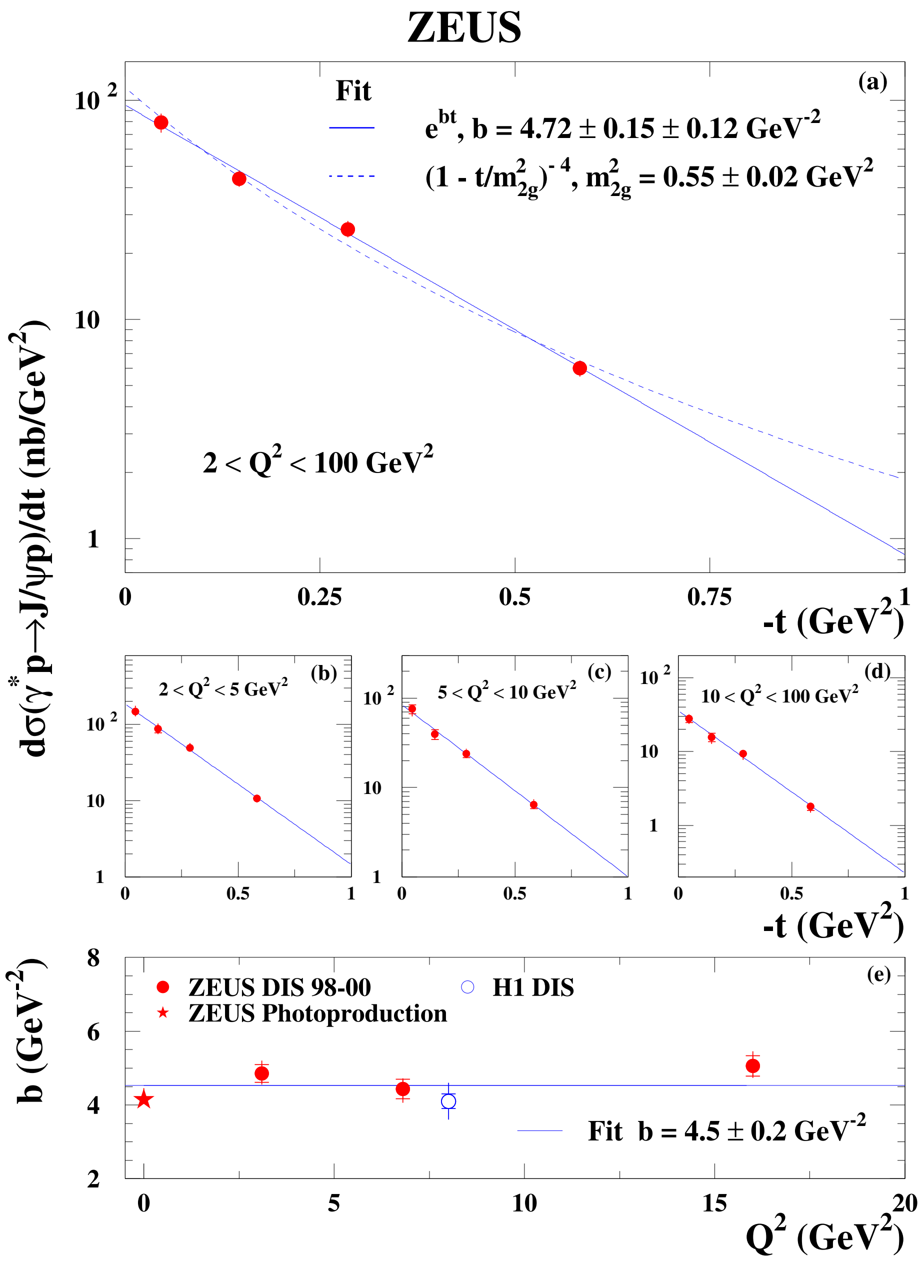
- assumptions on $c\bar{c}$ wave function
- corrections to the LO
- assumptions on GPDFs

- large uncertainty in normalisation
- models describe qualitatively data
- rise of σ with W related to increase in gluon density at low x
- $\sigma_L \simeq \frac{\alpha_S^2}{Q^6}|xG(x,Q^2)|^2$



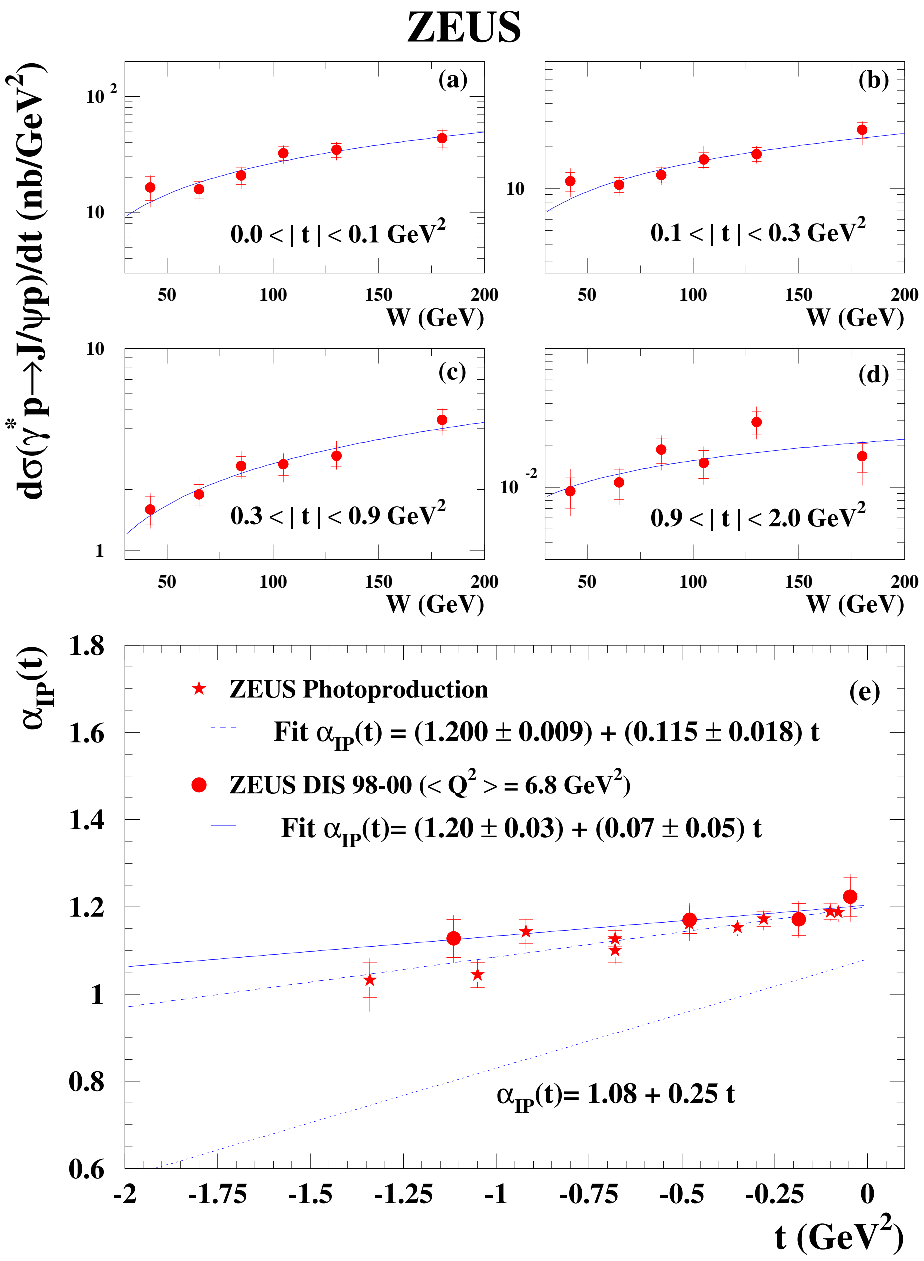
comparison for different PDFs

- strong sensitivity to (generalised) gluon distribution
- MRST02 has wrong shape in W
- CTEQ6M and ZEUS-S describe W and Q^2 dependence
- NLO order needed to constrain gluon density



t-dependence

- $d\sigma/dt \propto e^{bt}$
- b related to transverse size of the interaction $c\bar{c}$-p
- no dependence of b from Q^2, interaction dominated by size of p

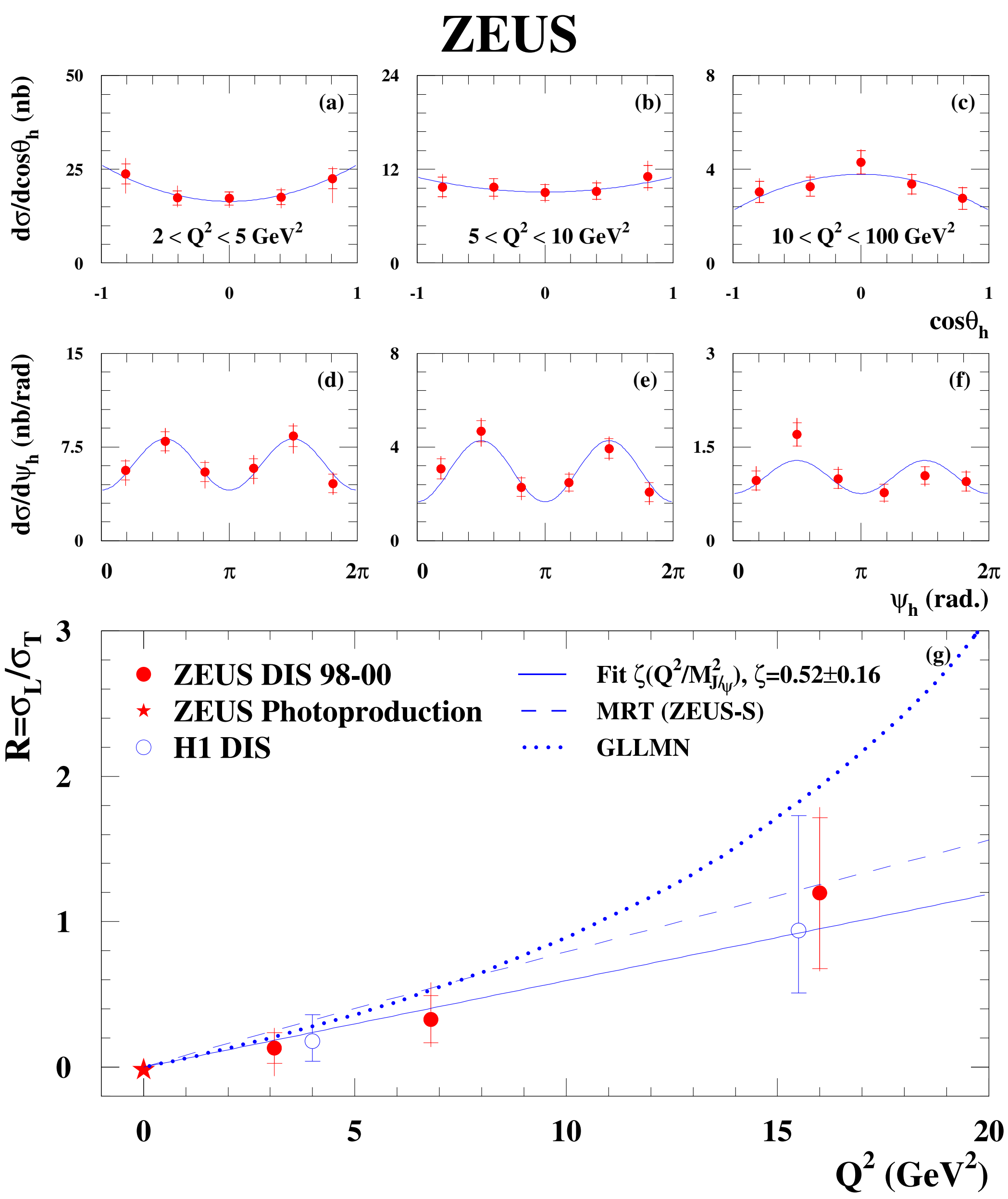


σ vs W in bins of t
Pomeron trajectory

- $\sigma/dt \propto W^{4(\alpha_{I\!P}(t)-1)}$

with $\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$

- small dependence of b from W
- $\alpha_{I\!P}(t)$ as measured in PHP
- $\alpha_{I\!P}(0)$ in agreement with NLO BFKL
- $\alpha_{I\!P}(t)$ not consistent with measurement of soft diffractive processes

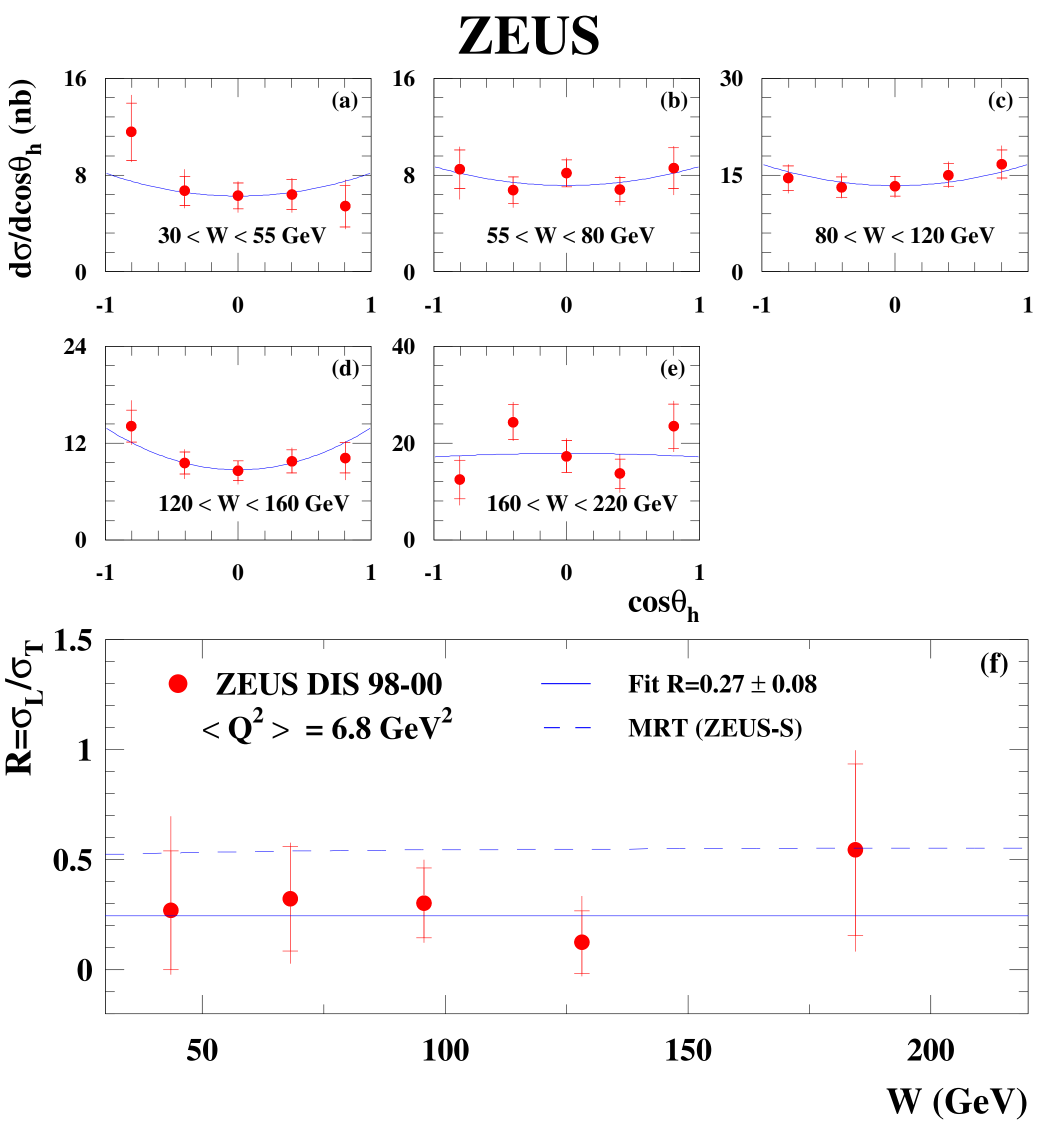


σ_L/σ_T vs Q^2

$$\frac{1}{N}\frac{dN}{d\cos\theta_h} = \frac{3}{8}\left[1 + r^{04}_{00} + (1 - 3r^{04}_{00})\cos^2\theta_h\right]$$

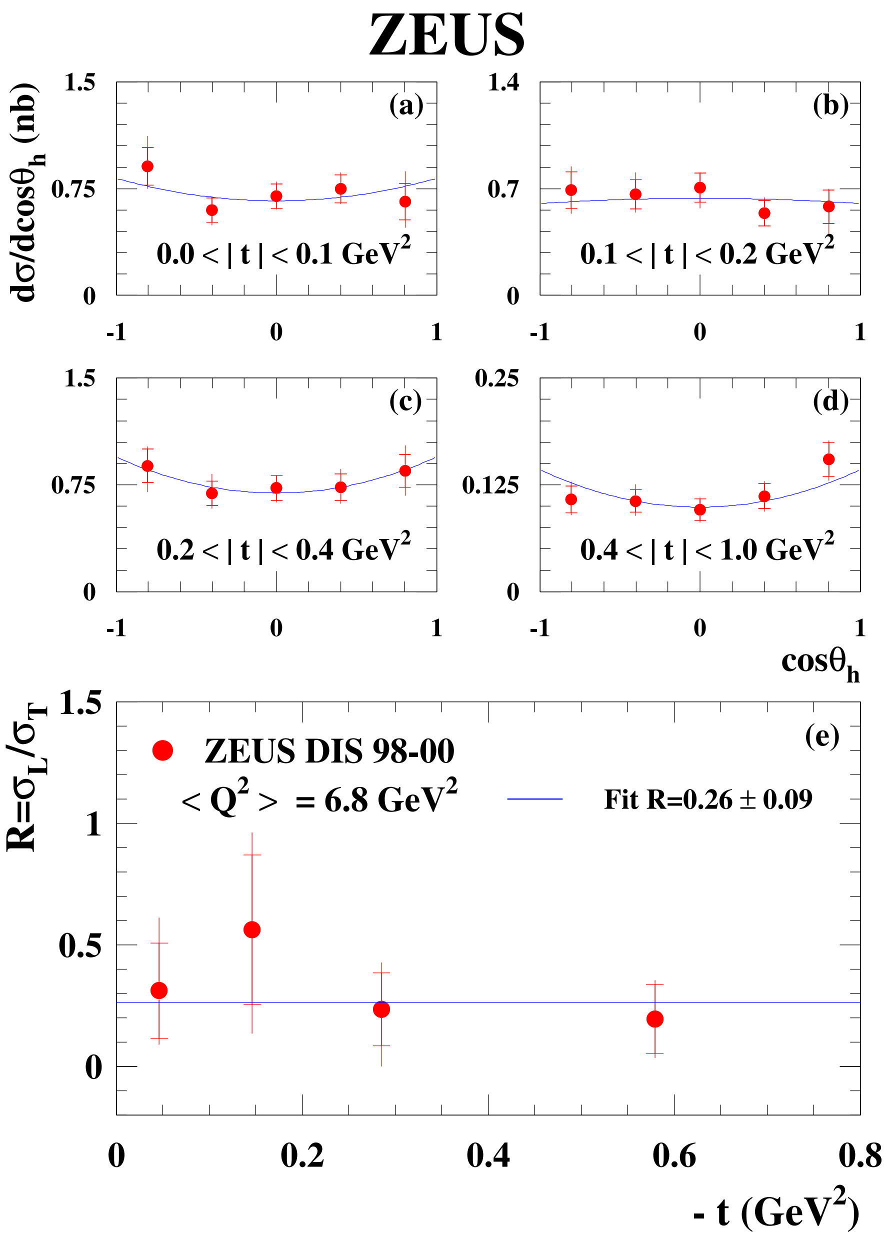
$$\frac{1}{N}\frac{dN}{d\psi_h} = \frac{1}{2\pi}\left[1 - \epsilon r^{1}_{1-1}\cos 2\psi_h\right]$$

- angular distributions allow to extract σ_L/σ_T
- $R = \frac{\sigma_L}{\sigma_T} = \frac{1}{\epsilon}\frac{r^{04}_{00}}{1-r^{04}_{00}}$
- σ_L and σ_T have different Q^2 dependence



σ_L/σ_T vs W

- in QCD models, R can depend on W
- MRT: σ_L and σ_T have the same W dependence



σ_L/σ_T vs t

- σ_L and σ_T have the same t dependence

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Summary

- precise measurement in wide kinematic range: $0.15 < Q^2 < 0.8$ and $2 < Q^2 < 100$ GeV, $30 < W < 220$ GeV $-t < 1$ GeV^2
- pQCD models describe data
- data exhibit a strong sensitivity to the gluon distribution in the proton
- full NLO calculations needed to constrain gluon density