12th International Workshop
on Deep Inelastic Scattering

Inelastic J/ψ with ZEUS

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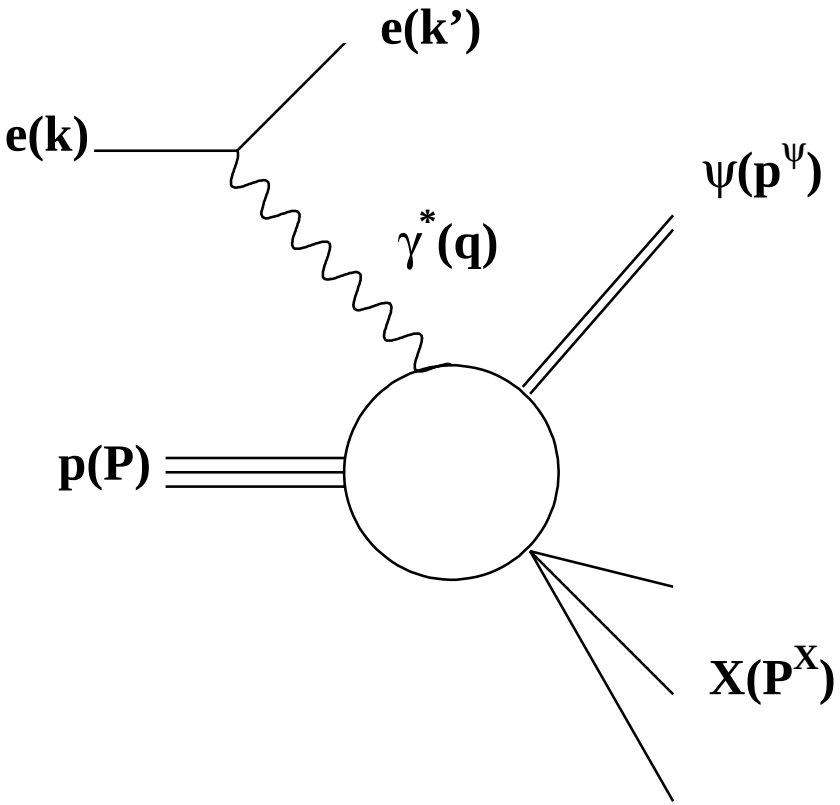
Outlook:

- kinematics and production channels
- J/ψ differential cross sections in PHP and DIS
- J/ψ helicity analysis in PHP
- conclusions

HERA kinematics



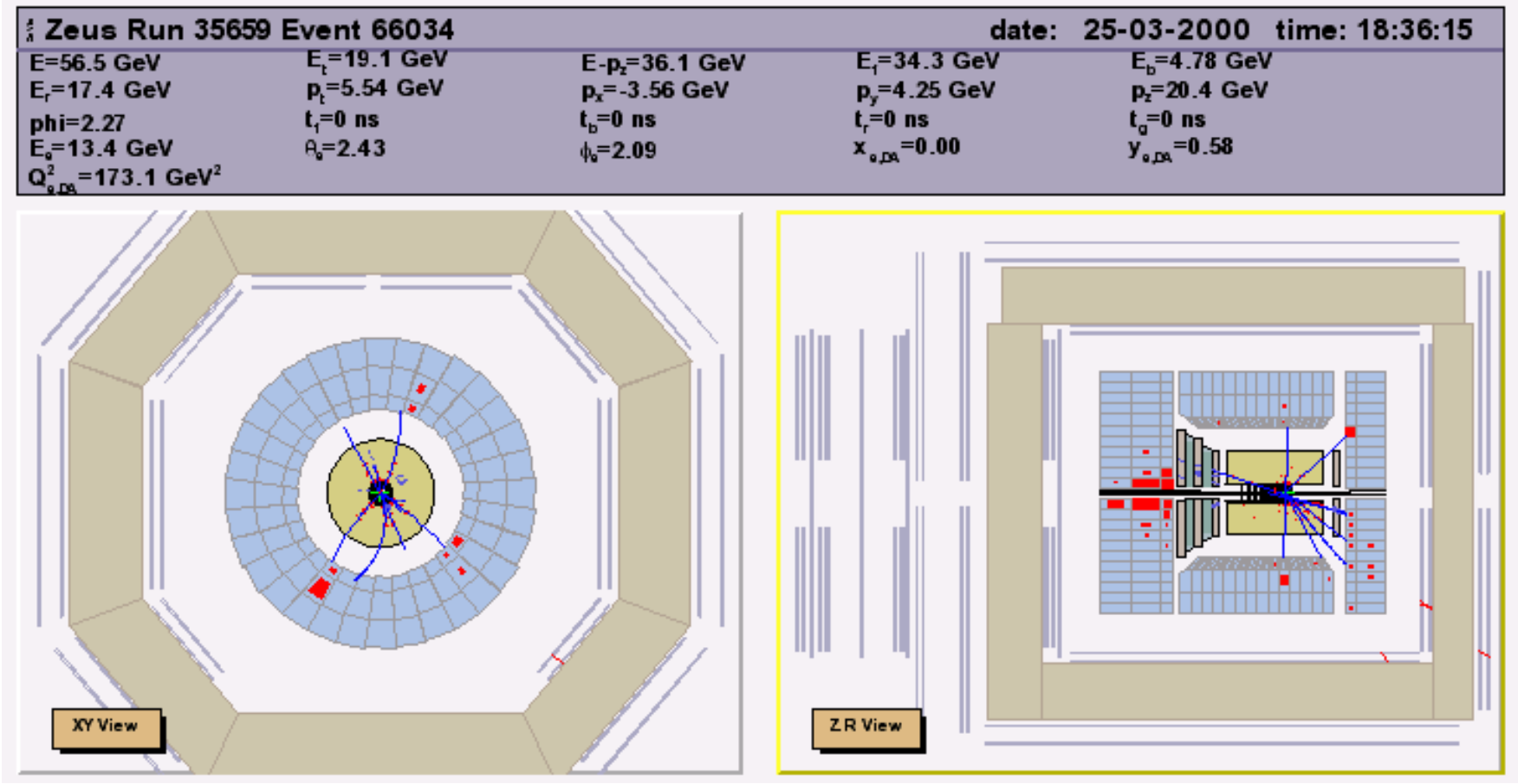
- $s = (P+k)^2$
- $Q^2 = -(k-k')^2$
- $W^2_{\gamma p} = (P+q)^2$
- $M_X^2 = (P^X)^2$
- $z = (P\ p^\psi) / (P\ q)$

  $= E(\psi)/E(\gamma^*)$

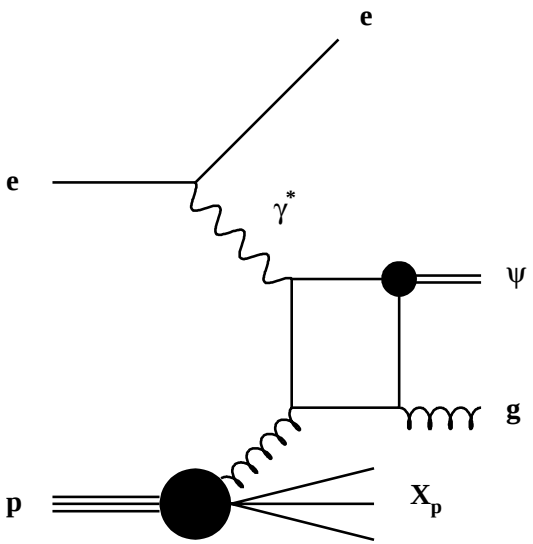
p rest frame

HERA kinematics

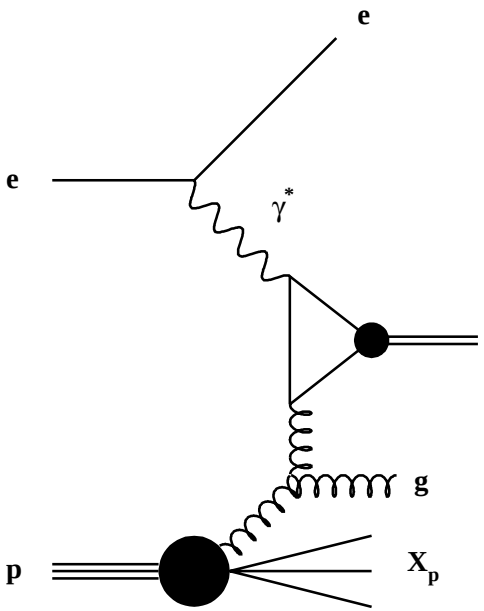
- DIS regime: scattered lepton in the main detector
- PHP regime: scattered lepton NOT in the main detector, $Q^2 < 1$ GeV^2



Inelastic charmonium production channels at HERA



- direct γ
- naïf CSM
- $0.2 < z < 0.9$
- 'only' free parameter fixed from $\Gamma(J/\psi \rightarrow l^+ l^-)$
- $g_p(x,\mu^2)$

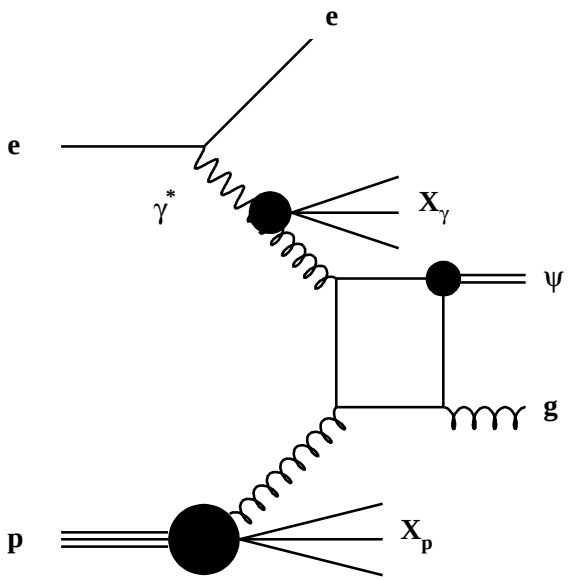


- direct γ
- CO model: allow the final state charm pair to evolve into the physical ψ state

$\Rightarrow$ new free parameters

- not only high z
- $g_p(x,\mu^2)$

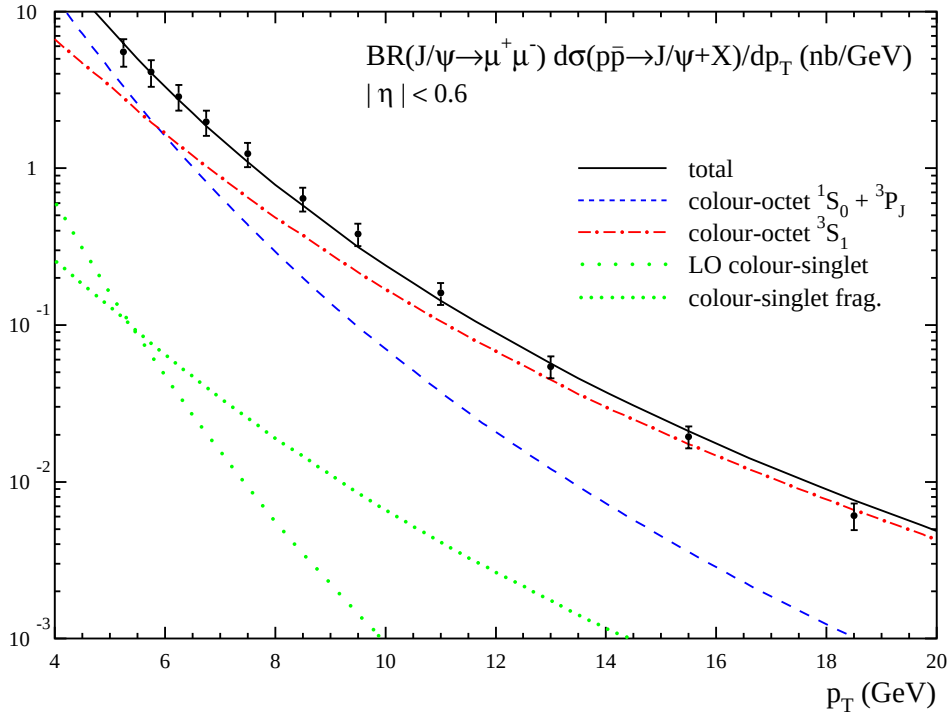
Inelastic charmonium production channels at HERA



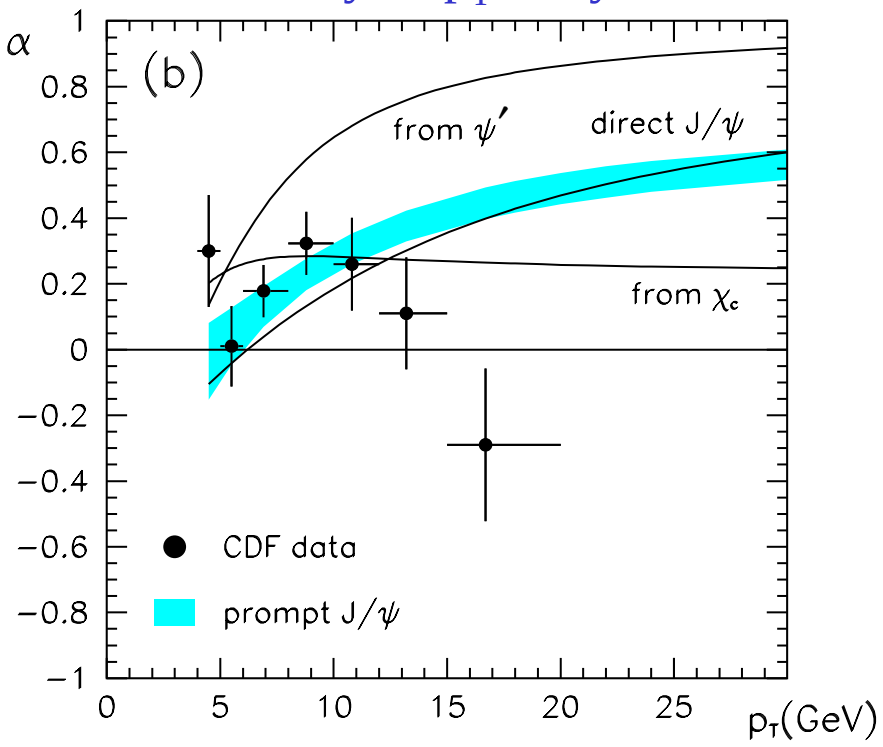
- resolved γ
- naïf CSM
- $z < 0.2$
- 'only' free parameter fixed from $\Gamma(J/\psi \rightarrow l^+ l^-)$
- $g_p(x,\mu^2) \otimes g_\gamma(x,\mu^2)$

J/ψ at CDF

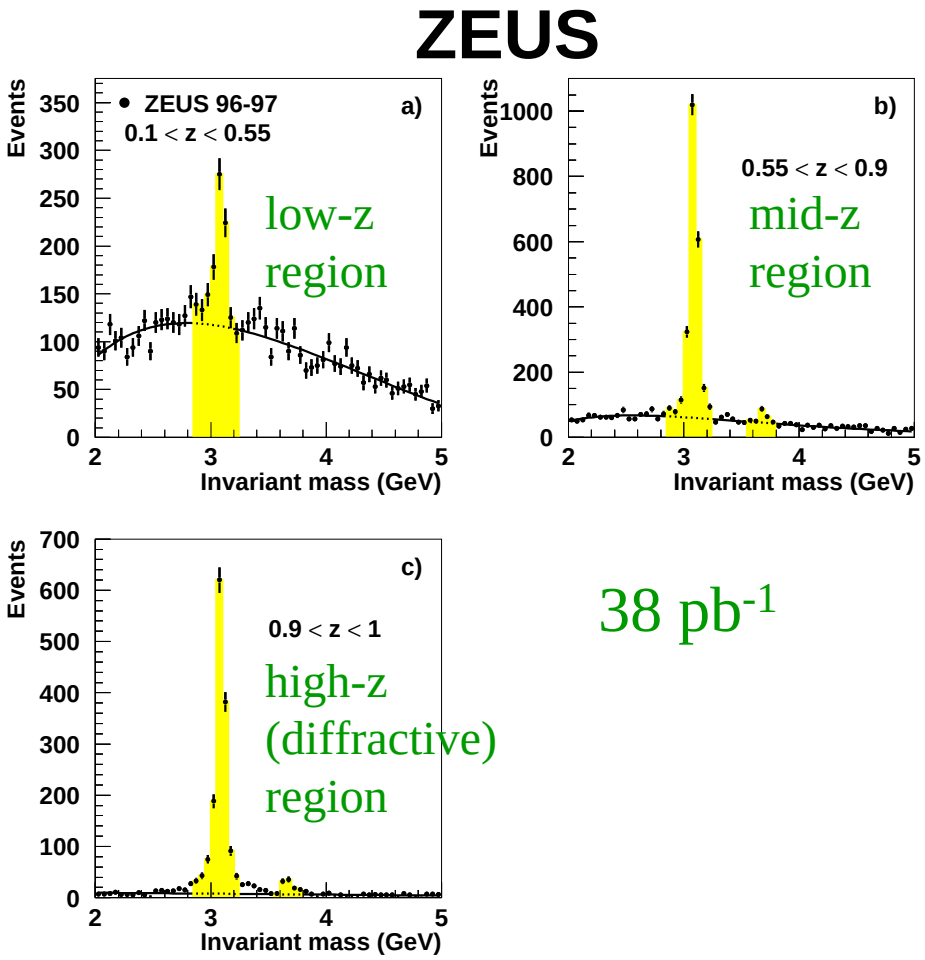
p_T differential cross section



helicity vs p_T analysis

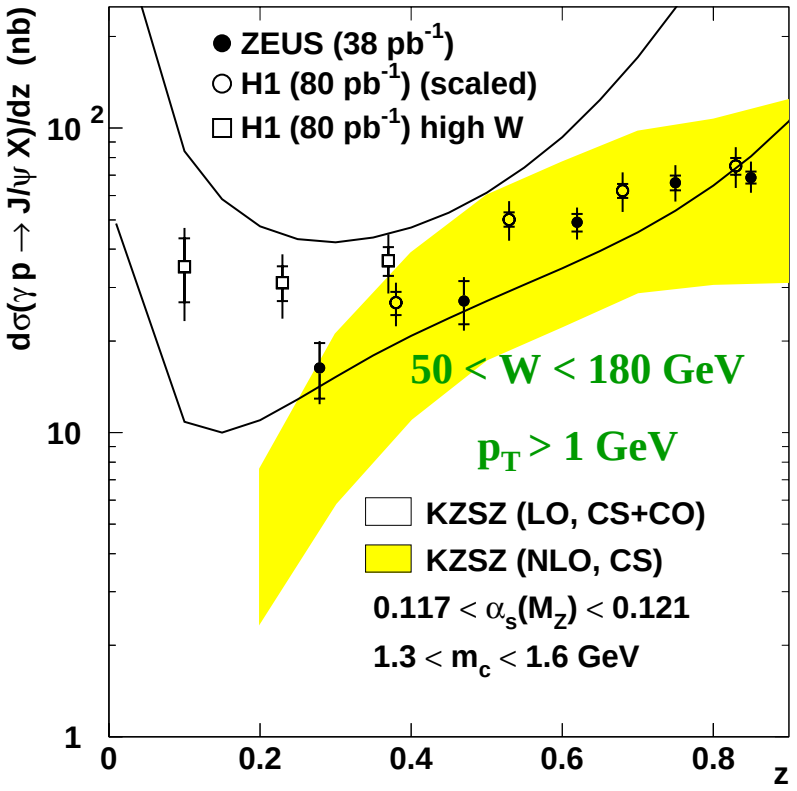


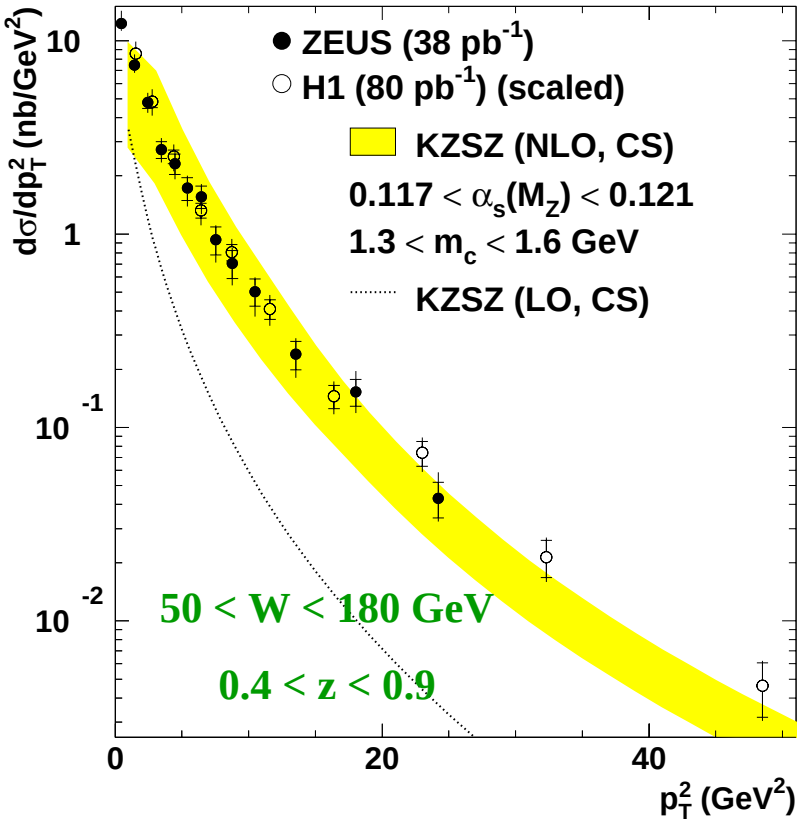
Inelastic charmonium signals



38 pb^{-1}

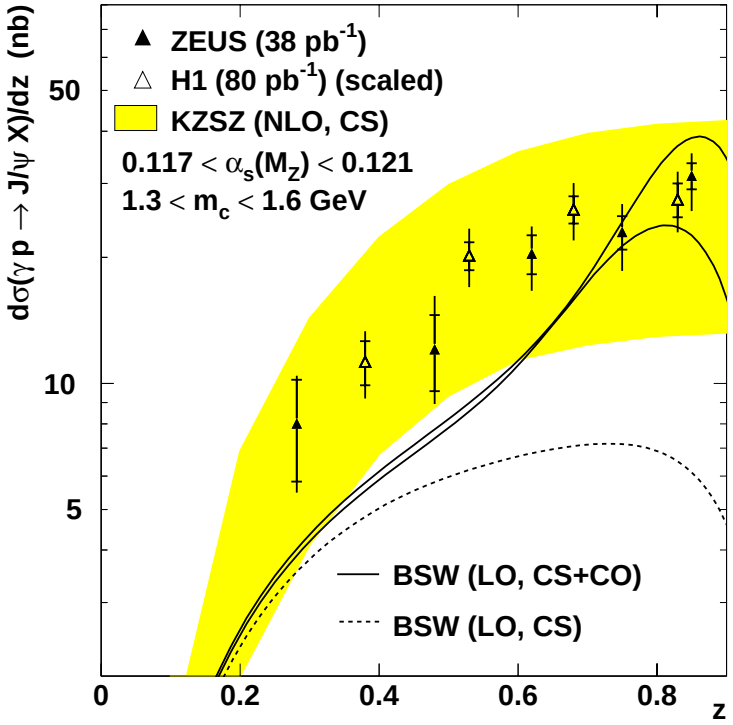
Inelastic J/ψ differential cross sections in PHP





- HERA initial state simple enough to have a NLO calculation in the naïve CSM scheme
- theoretical uncertainties does not allow strong conclusions about CO terms
- how to reduce them ?

Inelastic J/ψ differential cross sections in PHP



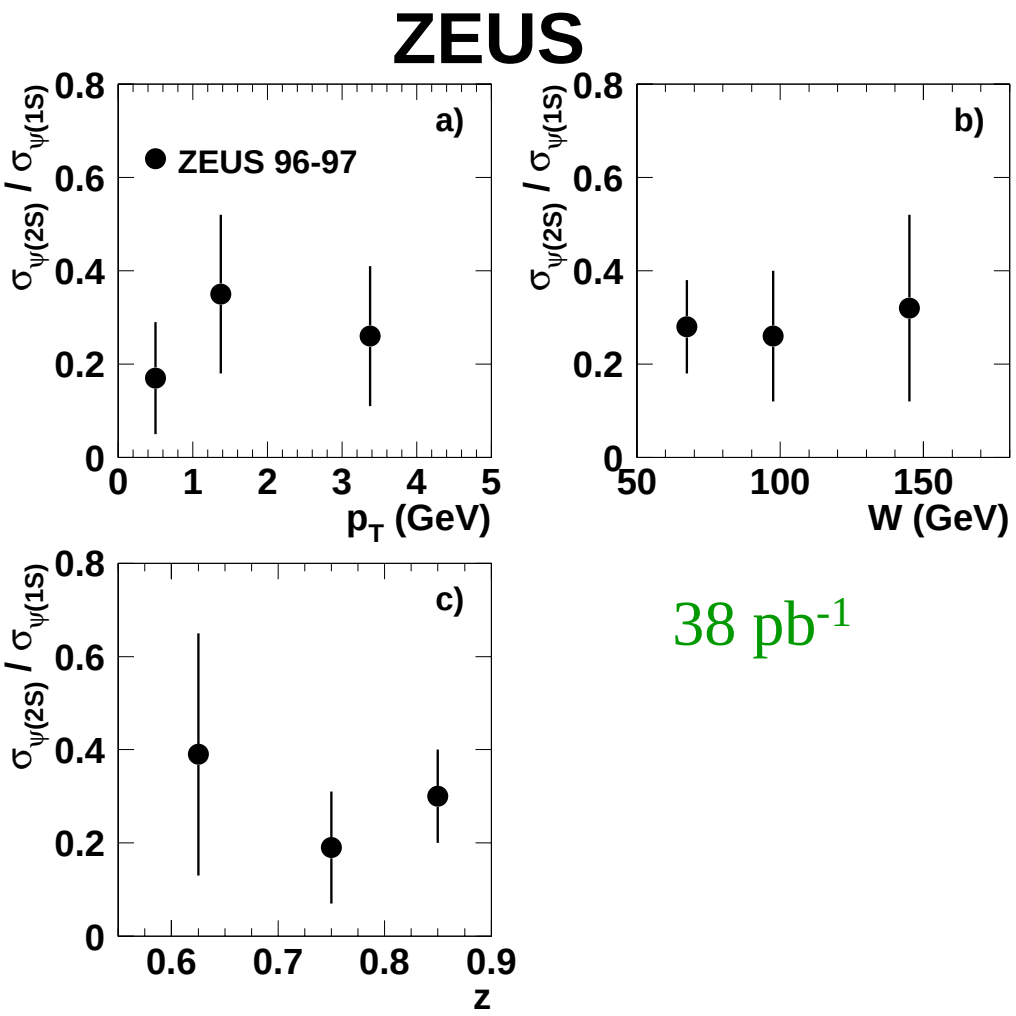
$50 < W < 180$ GeV

$p_T > 2$ GeV

- sizeable CO contributions
- higher scale ?
- better treatment of CO terms ?

J/ψ feed down

- at HERA mostly $\psi(2S) \rightarrow J/\psi X$
- B decays, χ_c radiative decays, … much smaller than at the TEVATRON

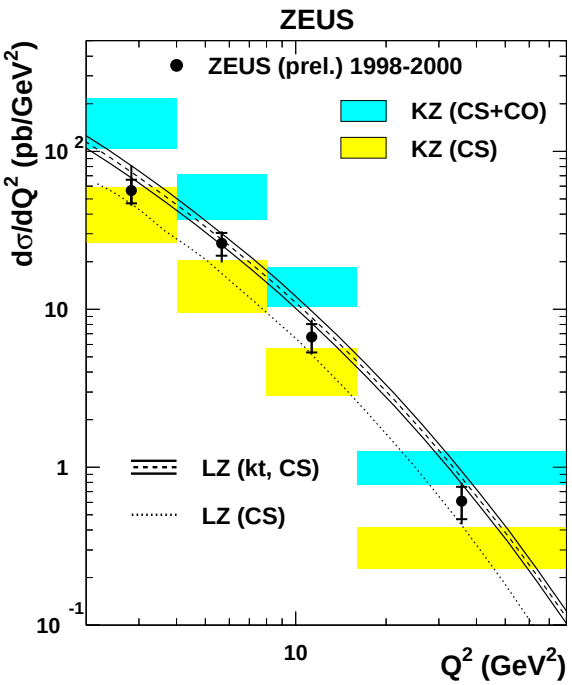


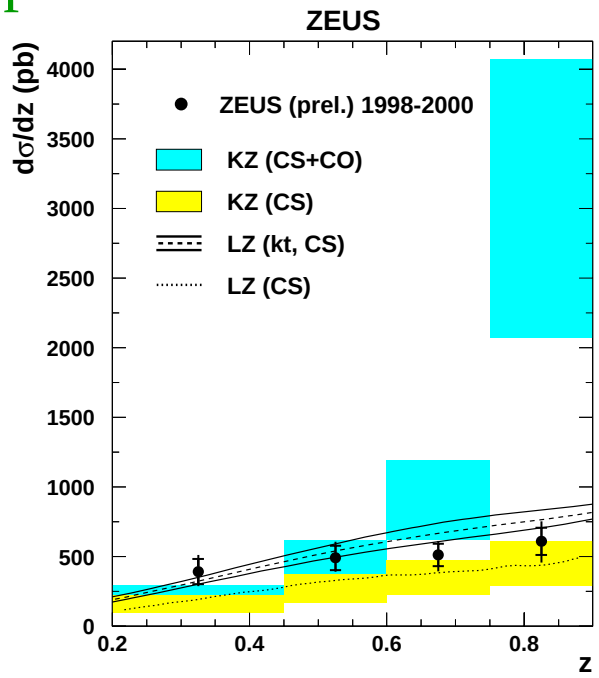
38 pb^{-1}

- $\psi(2S) \rightarrow J/\psi X$ increases the cross sections by 15 %
- NOT subtracted yet, unclear how to do it

Inelastic J/ψ differential cross sections in DIS

73 pb^{-1}





- smaller cross section w.r.t. PHP
- higher expected sensitivity to CO terms w.r.t. PHP

$Q^2 > 2$ GeV^2

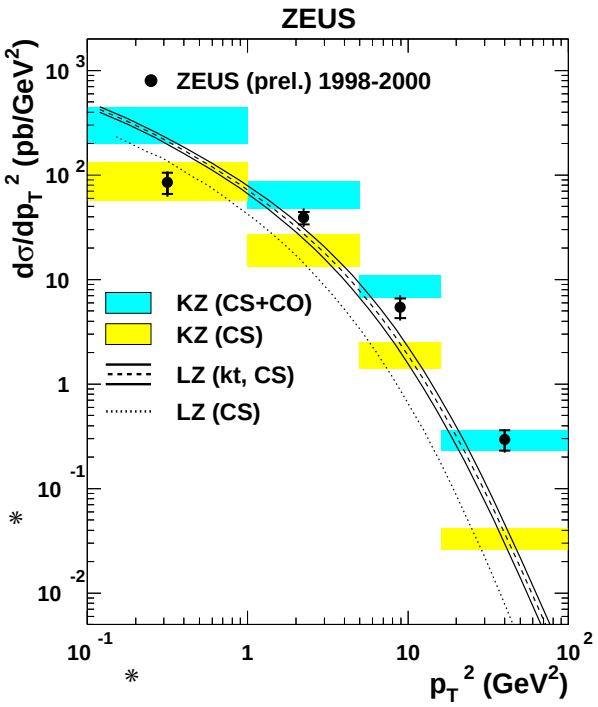
$50 < W < 250$ GeV

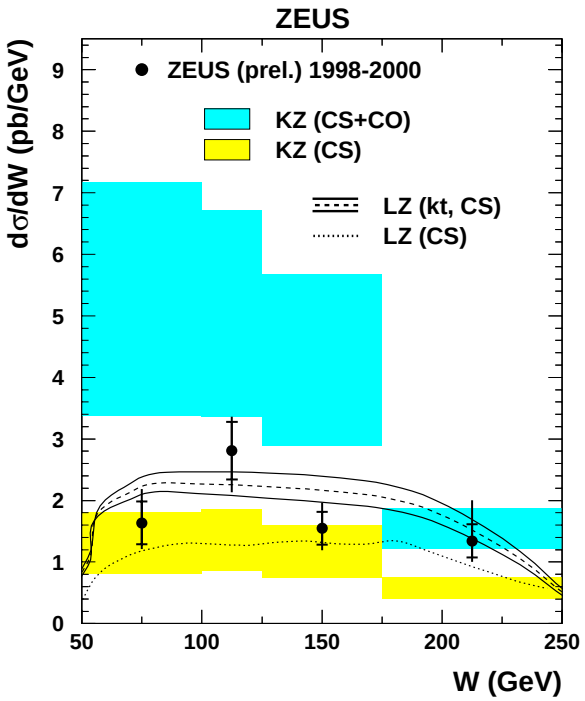
$0.2 < z < 0.9$

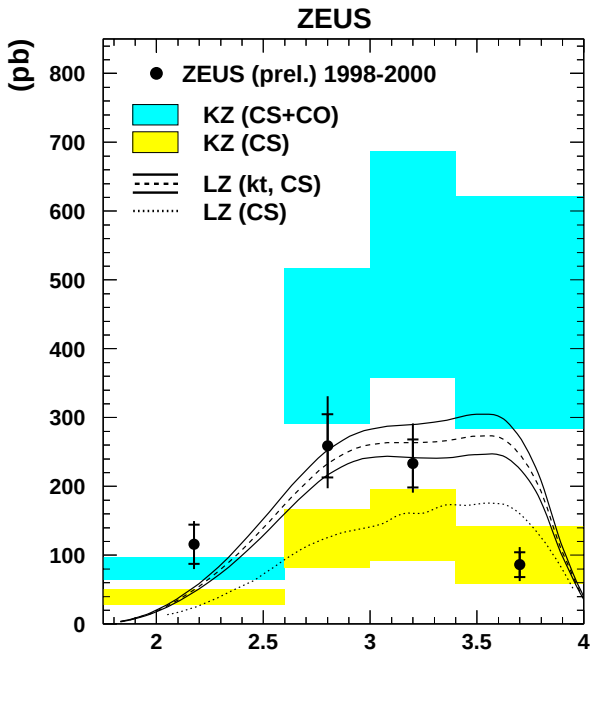
$-1.6 < y_{lab}(J/\psi) < 1.3$

- large theoretical uncertainties do not allow strong conclusions
- inclusion of gluon k_T looks promising

Inelastic J/ψ differential cross sections in DIS







- like in PHP, the only distinctive variable is z
- how can we reduce the theoretical uncertainties ?

J/ψ helicity measurements in PHP

- helicity ≡ study of the μ^+ polar and azimuthal distributions in the J/ψ rest frame

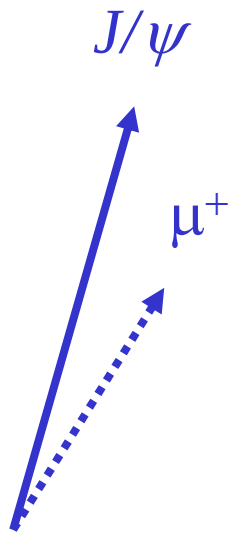
- choose a quantization axis in the J/ψ rest frame : target frame, quantization axis ≡ opposite of the incoming proton direction in the J/ψ rest frame

- helicity master formulas:

$1/\sigma\ d^2\sigma/(d\cos\theta^*\ dy) \propto 1 + \lambda(y)\cos^2\theta^*$

$1/\sigma\ d^2\sigma/(d\phi^*\ dy) \propto 1 + \lambda(y)/3 + \nu(y)/3\cos 2\phi^*$

$y = p_T$ or z



θ^*: polar analysis
ϕ^*: azimuthal analysis

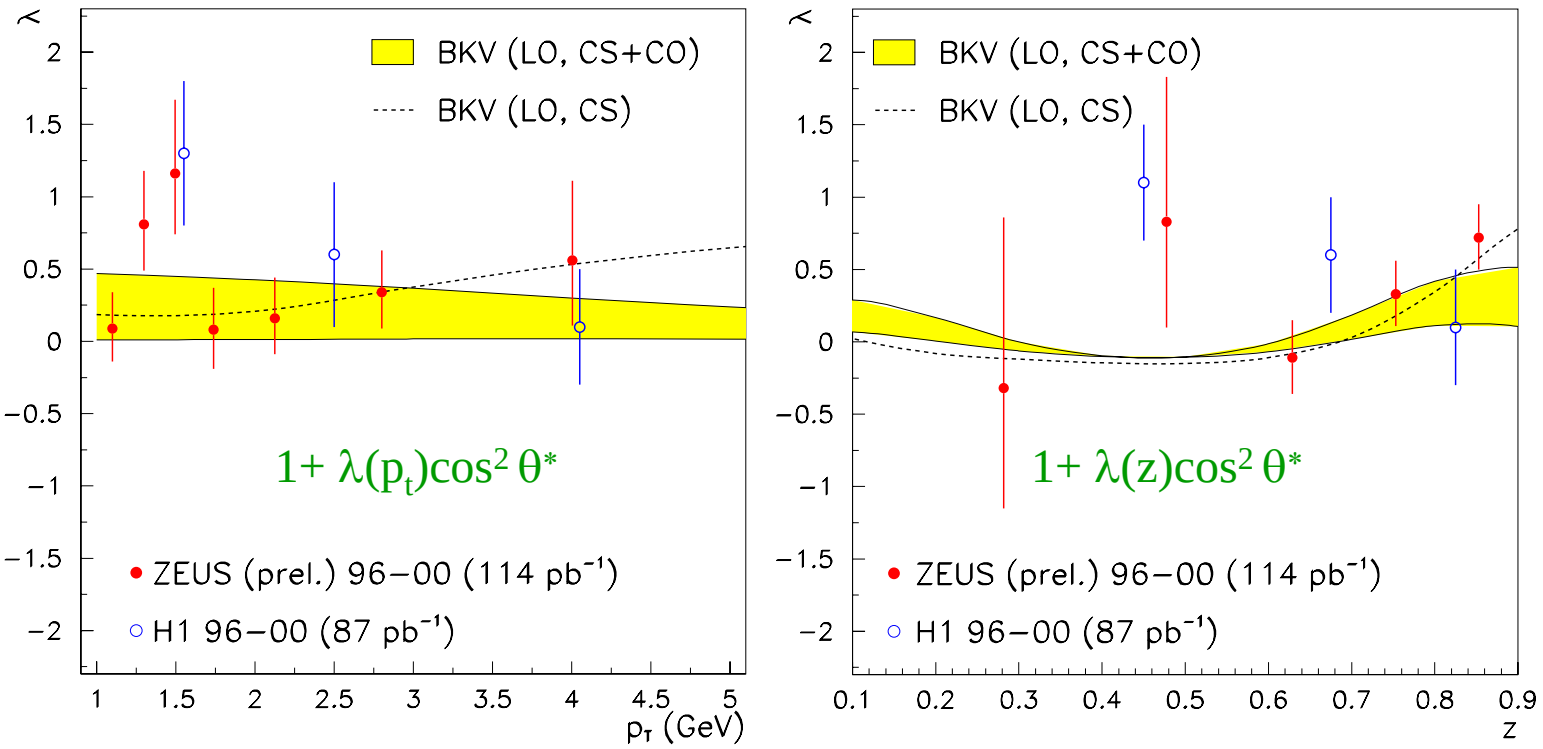
- helicity ⇔ shape measurements

⇔ insensitive to the normalization of the predicted cross section (α_s, m_c …)

⇔ have to fit a distribution in each bin ⇔ ~ 1000 of J/ψ events per bin

J/ψ helicity measurements in PHP

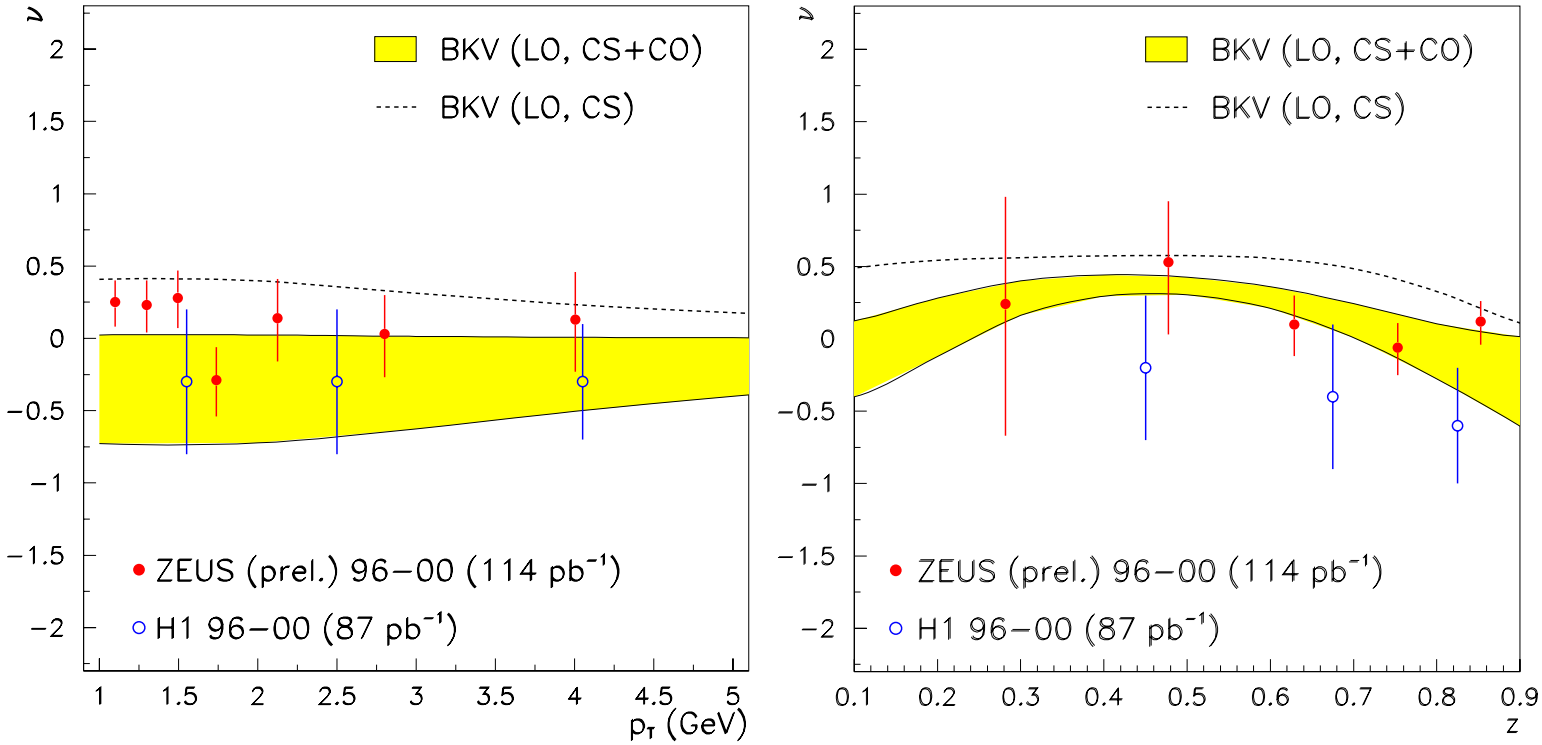
polar analysis:



- CS / CS+CO predictions different only at high p_T
- ZEUS / H1 results statistically not yet significant

J/ψ helicity measurements in PHP

azimuthal analysis:



- some hints of deviations from the naïve CS expectations
- statistically not yet significant, would be nice if the experimental errors could be halved …

Conclusions

- inelastic J/ψ cross sections have been analyzed both in the PHP and in the DIS regimes
  - most interesting distribution: z differential cross section, due to the different behavior of CS and CO terms
  - experimental data are rather precise but the theory suffer from large uncertainties hence no strong conclusions can be reached
- to be less affected by the theoretical uncertainties the helicity distributions were studied, results quite interesting but not statistically significant yet, need HERA II data
- likely we are on the right track but 30 years after the ψ discovery we do not yet know how it is produced … a quantitative picture is still missing !
- a lot of exchange between theorist and experimentalist is mandatory in order to make further progresses