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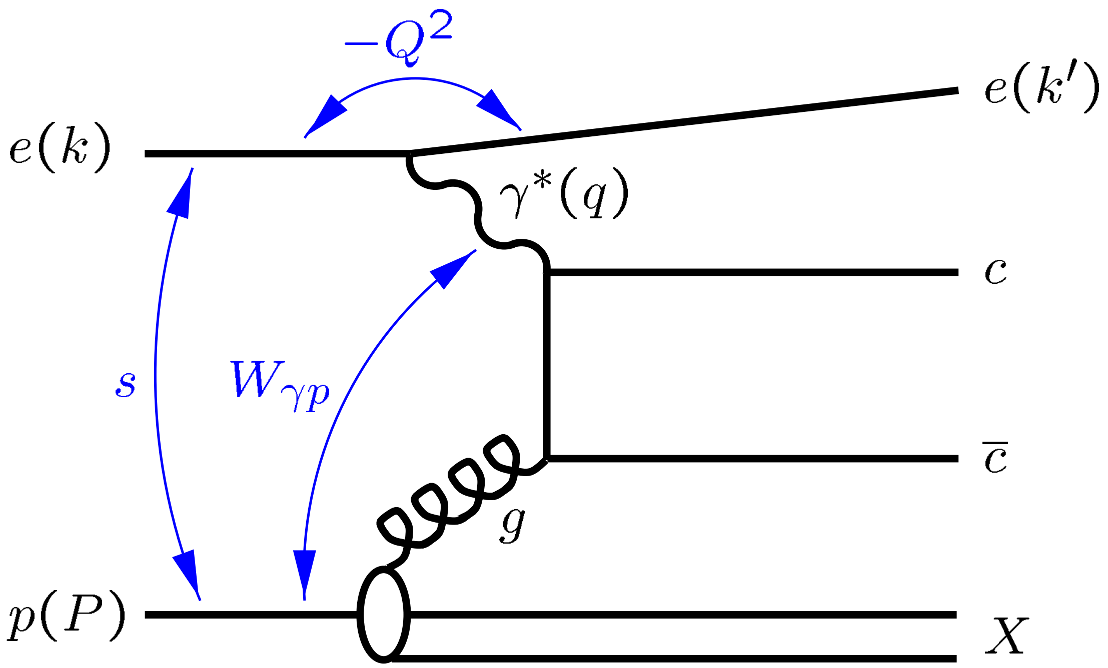
Inelastic J/ψ production at HERA

contents:

- introduction
- production mechanisms
- J/ψ photoproduction at "medium" z
- "low" z J/ψ photoproduction
- inelastic ψ' photoproduction
- outlook

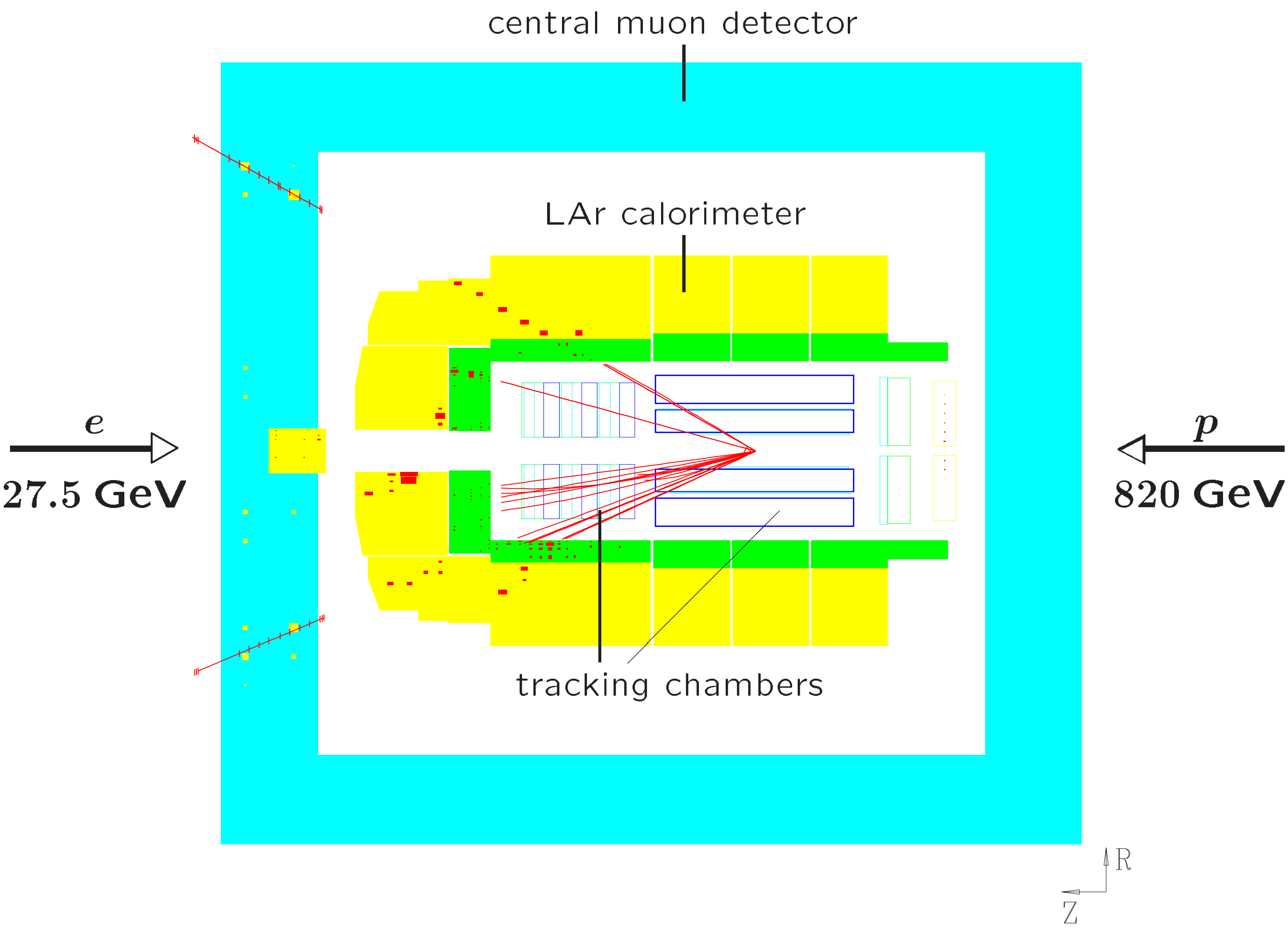
introduction



kinematic variables:

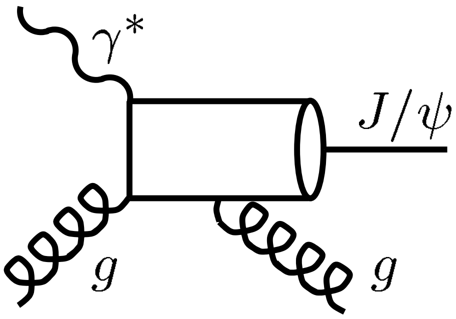
$$
\begin{aligned}
Q^2 &= -q^2 \\
s &= (P+k)^2 \approx (300\,\text{GeV})^2 \\
W_{\gamma p} &= \sqrt{(P+q)^2}(=W) \\
z &= \frac{p_\psi \cdot P}{q \cdot P} = \frac{E^*_\psi}{E^*_\gamma} \text{ in proton rest frame}
\end{aligned}
$$

photoproduction ($Q^2 < 1\,\text{GeV}^2$): scattered e^+ not seen in main detector

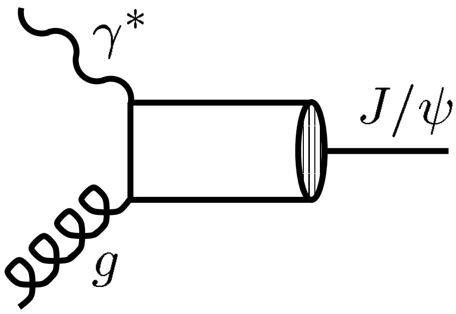

central muon detector
LAr calorimeter
tracking chambers
e
27.5 GeV
p
820 GeV
R
Z

production mechanisms

- direct photon gluon fusion: $z \gtrsim 0.3$

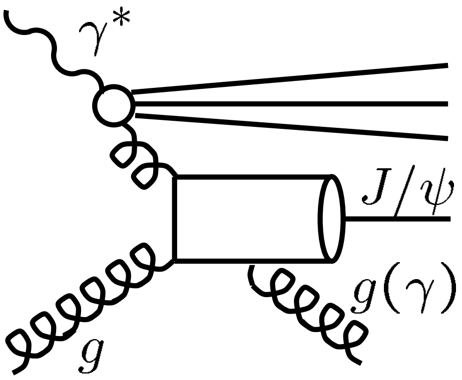


Colour Singlet Model
one parameter
fixed from $\Gamma_{\psi \to l^+ l^-}$

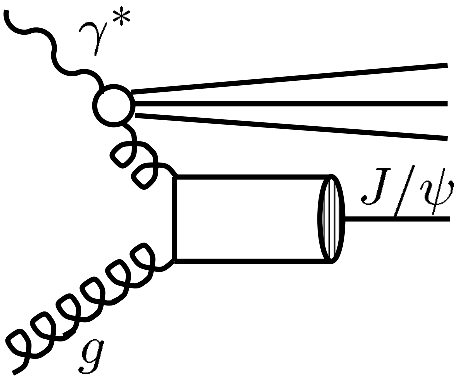


Colour Octet Model
additional free params.
CO matrix elements

- resolved photon processes (gluon gluon fusion): $z \lesssim 0.3$



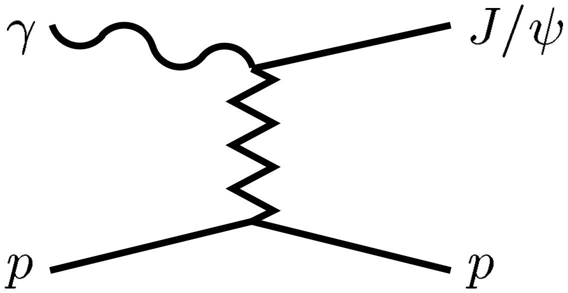
Colour Singlet Model



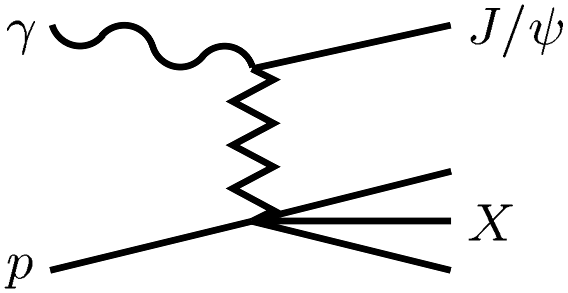
Colour Octet Model

production mechanisms

- background from diffraction



elastic diffraction
$z = 1$



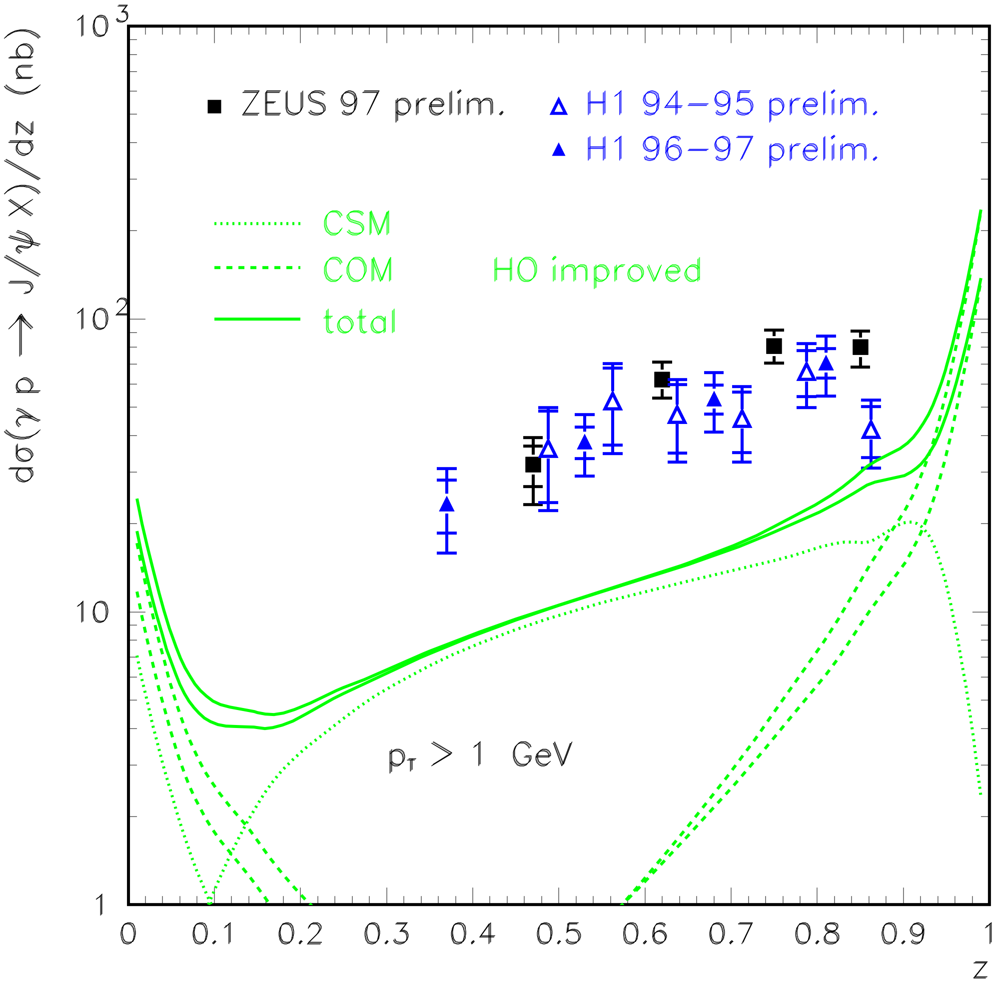
proton dissociation
$z \approx 1$

can be suppressed by cuts on additional activity in the detector:

– additional tracks (H1)

– energy deposits along the outgoing proton direction (ZEUS)

photoproduction at “medium“ z

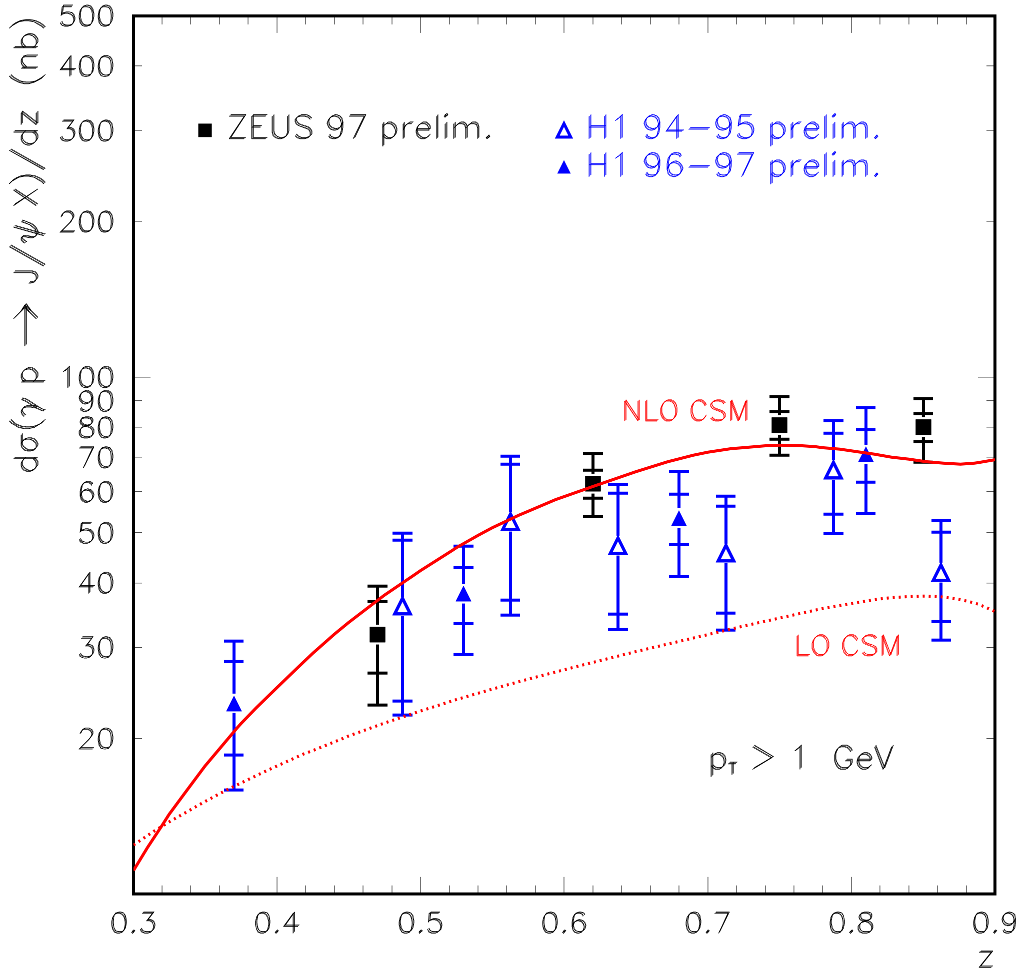


- $\psi' \to J/\psi\, X$ not subtracted (∼ 15%)
- hard subprocess at LO, CO MEs extracted with HO corrections from p_T spectrum of prompt J/ψ producion in $p\bar{p}$ collisions (factor ∼ 10 lower than LO)
- CS matrix element fixed from $\Gamma_{\psi \to l^+ l^-}$

⇒ substantial k factor (∼ 3) needed

⇒ direct photon gluon fusion ($0.3 \lesssim z \lesssim 0.9$) at HERA not very sensitive to CO contributions

photoproduction at "medium" z

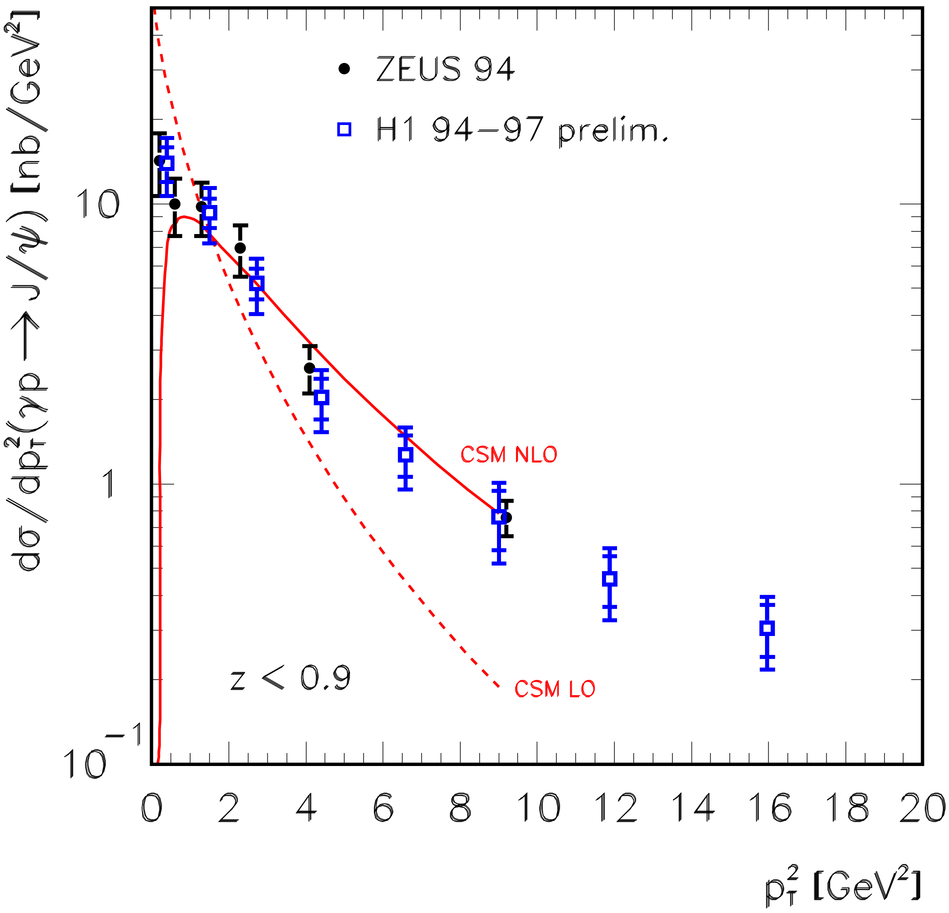


- full NLO calculation of the direct photon gluon fusion in the CSM

- GRV, $m_c = 1.4\,\text{GeV}$, $\Lambda^{(5)} = 300\,\text{MeV}$
  $m_c = 1.55\,\text{GeV}$, $\Lambda^{(5)} = 215\,\text{MeV}$ lowers theory a factor of ~ 3

$\Rightarrow$ shape is well described in NLO

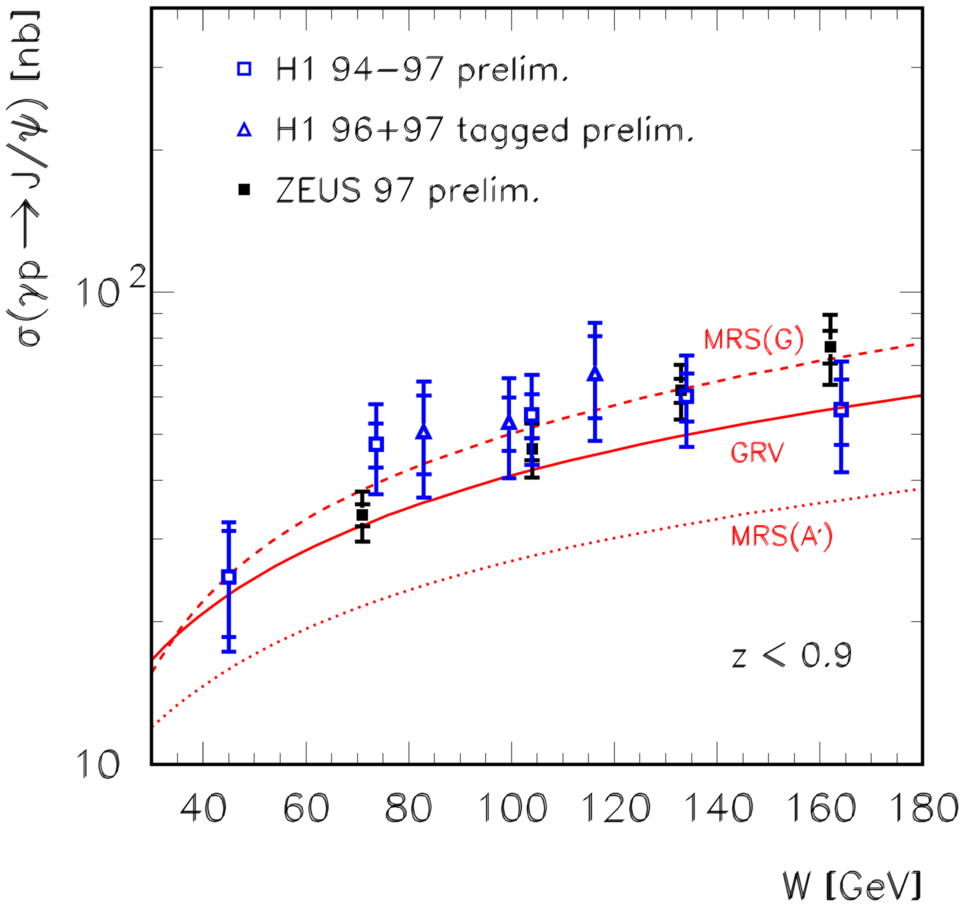
photoproduction at “medium“ z



- full NLO calculation of the direct photon gluon fusion in the CSM
- NLO calculation breaks down for $p_T \to 0$

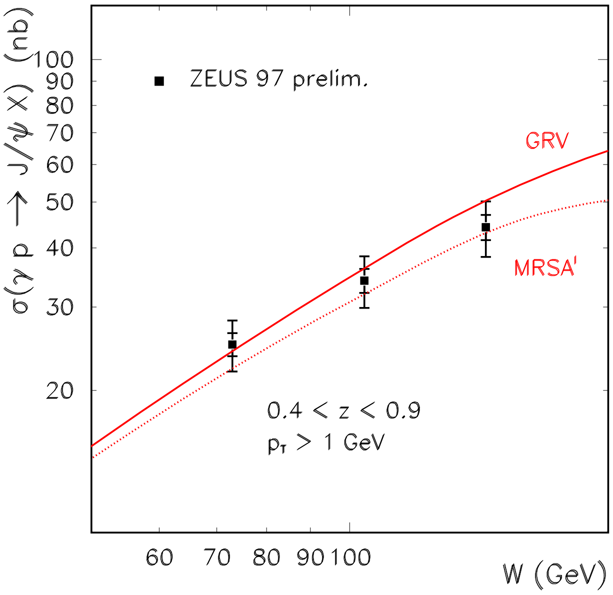
$\Rightarrow$ shape is well described in NLO for $p_T > 1$ GeV

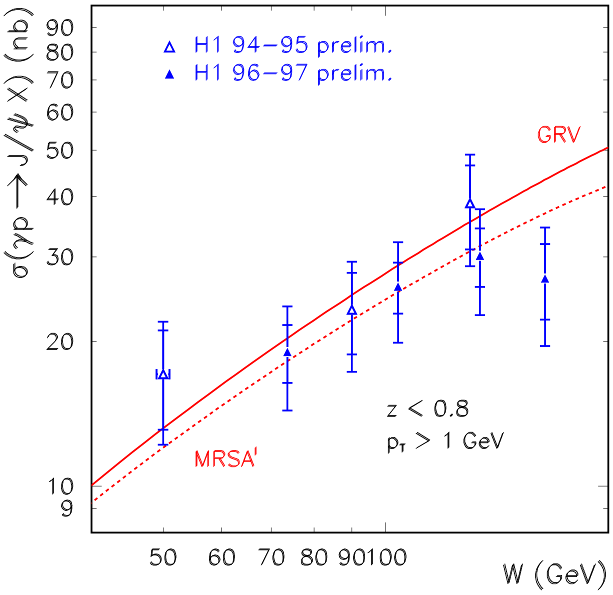
photoproduction at “medium“ z



- full NLO calculation of the direct photon gluon fusion in the CSM
- NLO calculation not very reliable for $p_T \to 0$
- shape is well described
- big influence of different pdf's

photoproduction at “medium“ z





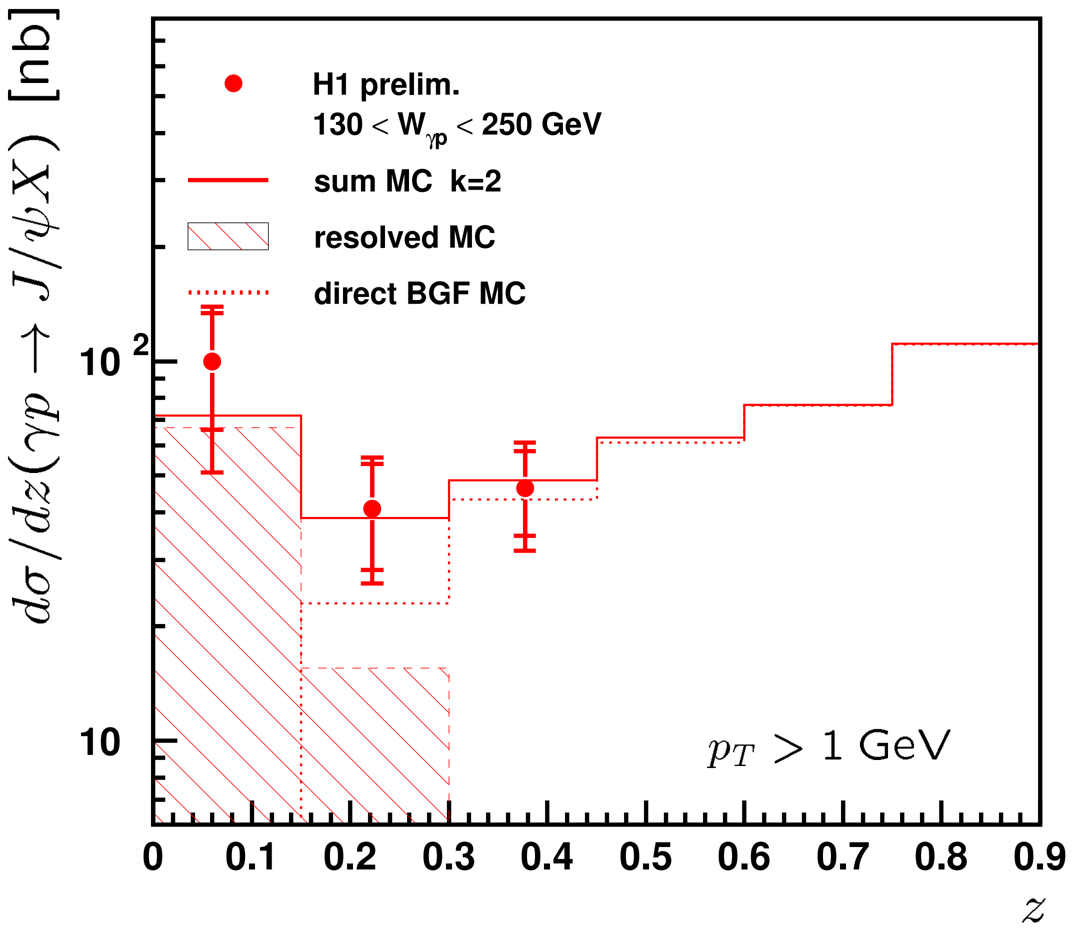
- full NLO calculation of the direct photon gluon fusion in the CSM
- NLO calculation more reliable
- smaller influence of different pdf's

“low“ z photoproduction

problem: due to the detector acceptance lower z is correlated with higher $W_{\gamma p}$, especially for resolved photon processes

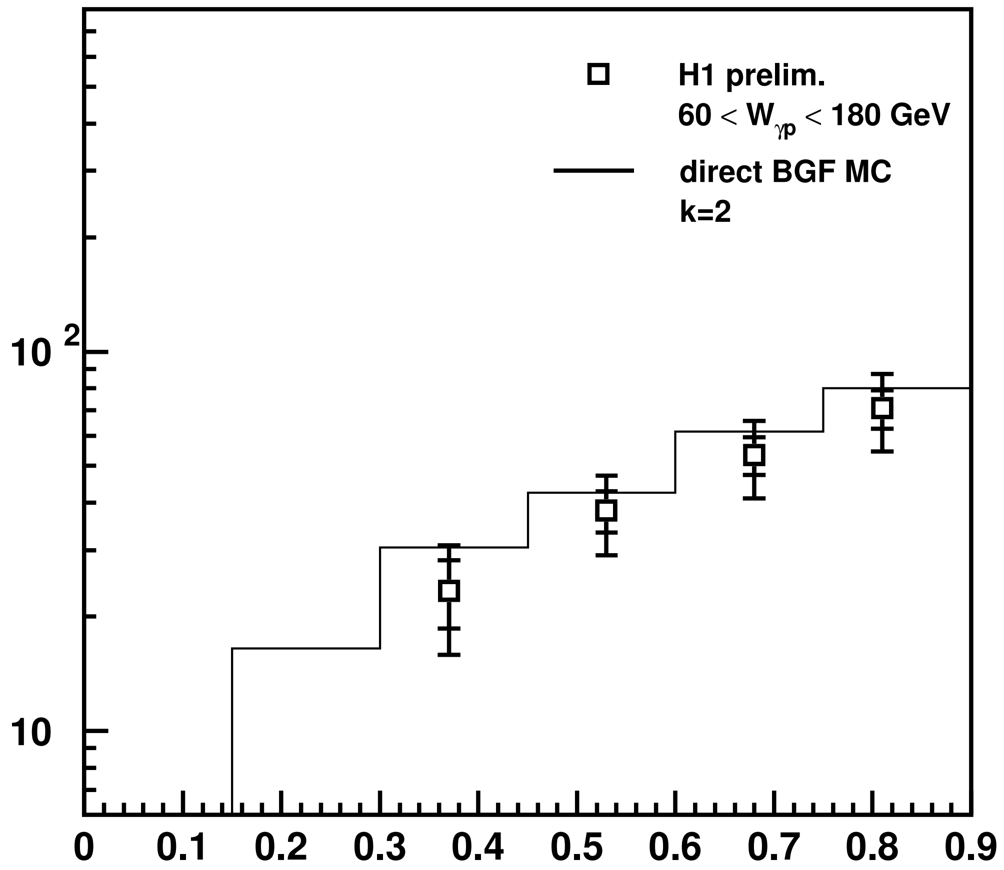
$$0.3 < z < 0.9 \longrightarrow z < 0.45$$
$$60 < W_{\gamma p} < 180 \text{ GeV} \longrightarrow 130 < W_{\gamma p} < 250 \text{ GeV}$$

$\Rightarrow$ low z not directly comparable with medium z

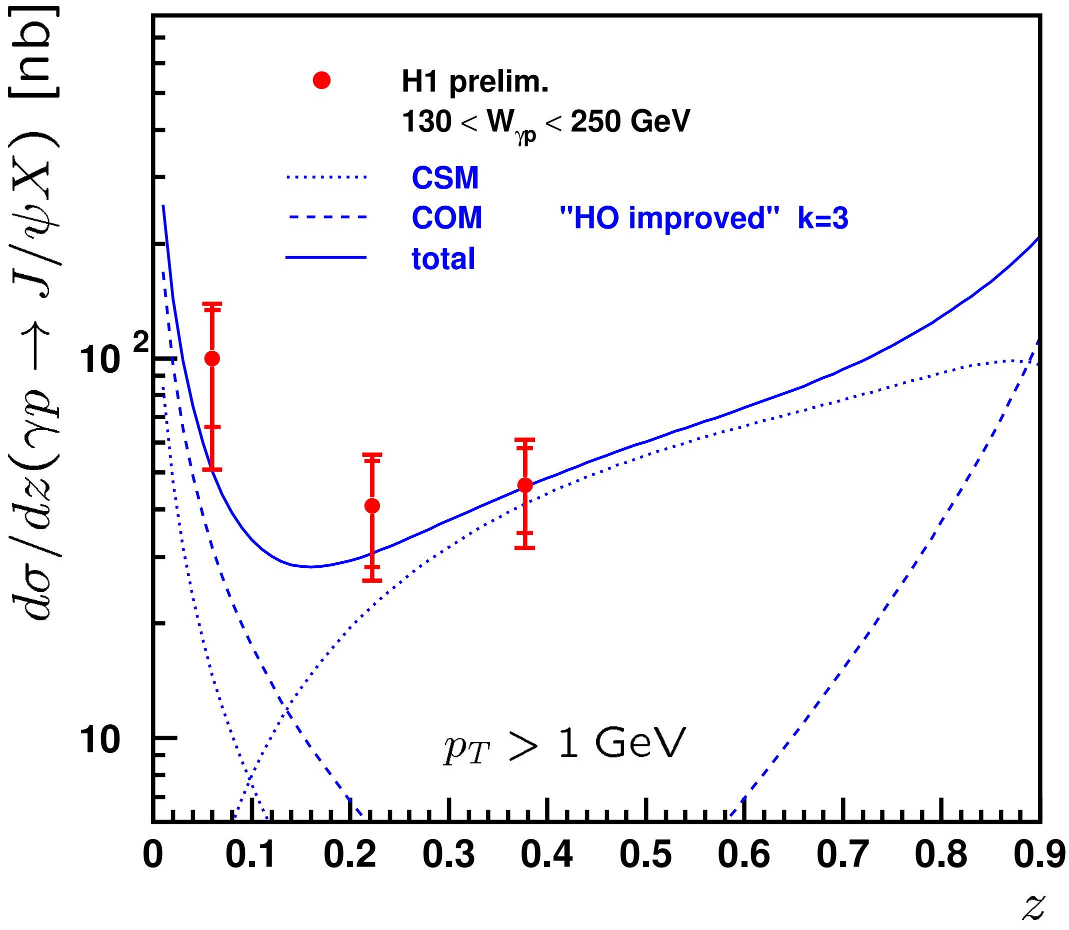


- MC: EPJPSI photon gluon and gluon gluon fusion
- k factor of 2 used for direct and resolved MC

$\Rightarrow$ resolved photon contributions needed to describe data at low z


H1 prelim.
60 < $W_{\gamma p}$ < 180 GeV
direct BGF MC
k=2
10^2
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

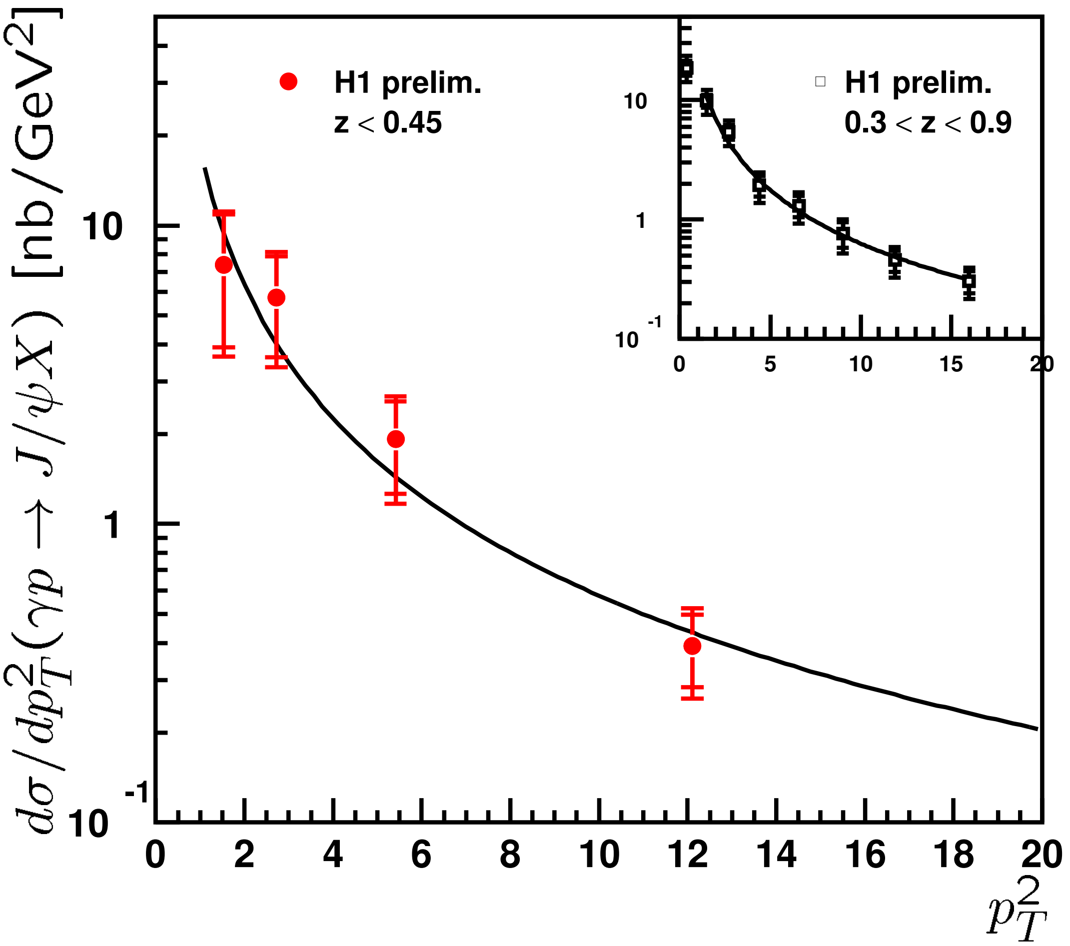
“low“ z photoproduction



- HO improved: hard subprocess still at LO, CO MEs extracted with HO corrections
- proton: CTEQ5M, $\Lambda^{(4)} = 326\,\mathrm{MeV}$, photon: GRV HO
- 15% contribution from $\psi' \to J/\psi\, X$ included in theory curves
- substantial k factor (~ 3) needed

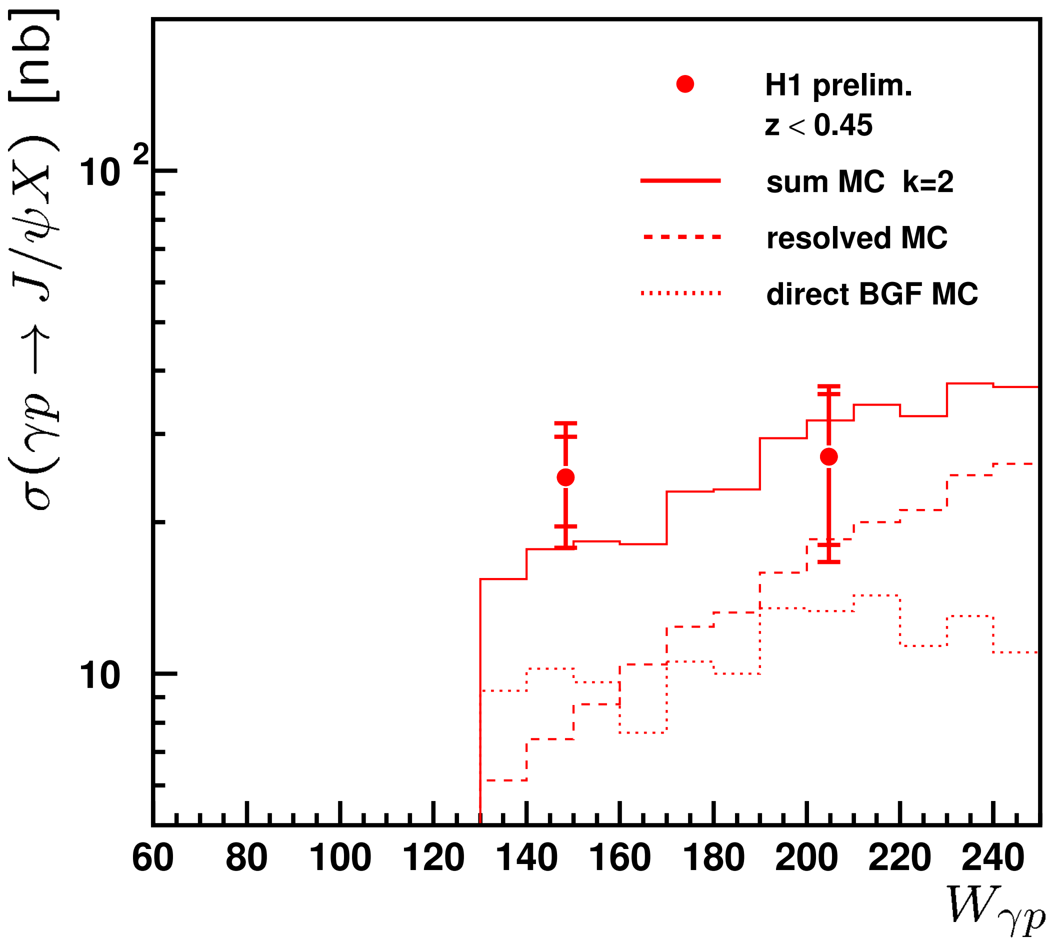
$\Rightarrow$ with present statistics no decision on CSM or COM possible

“low“ z photoproduction



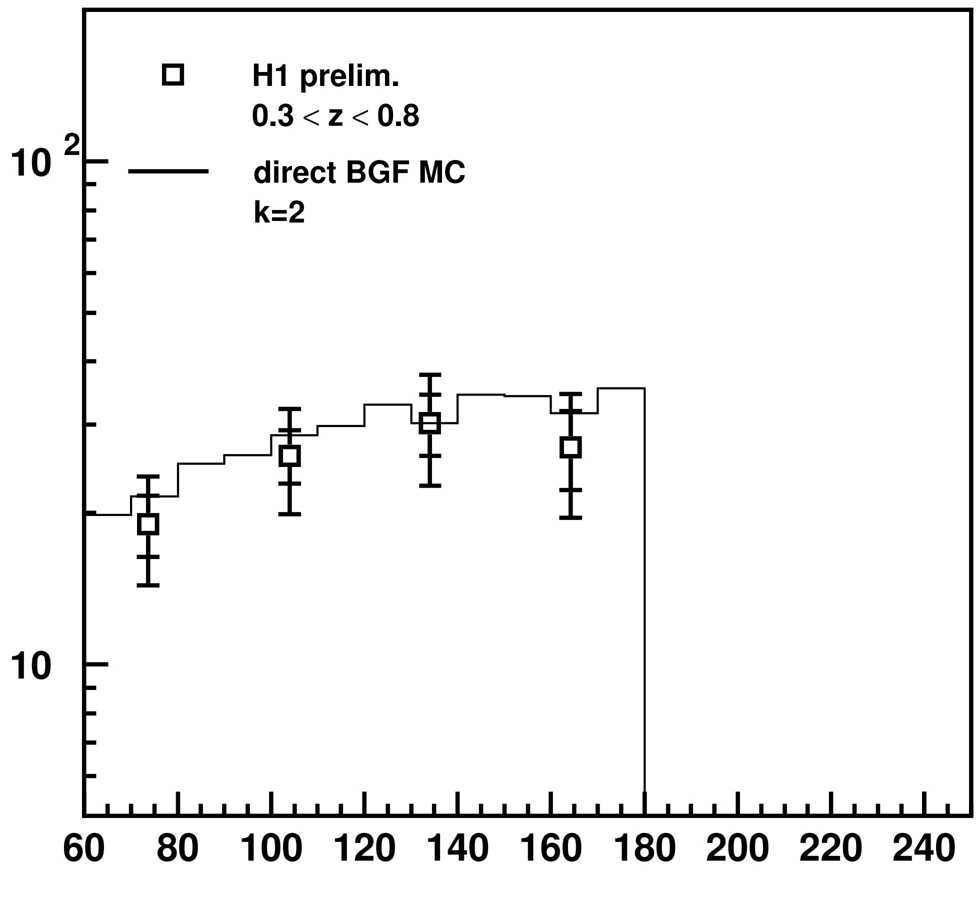
fit to medium z describes shape of data well

“low“ z photoproduction

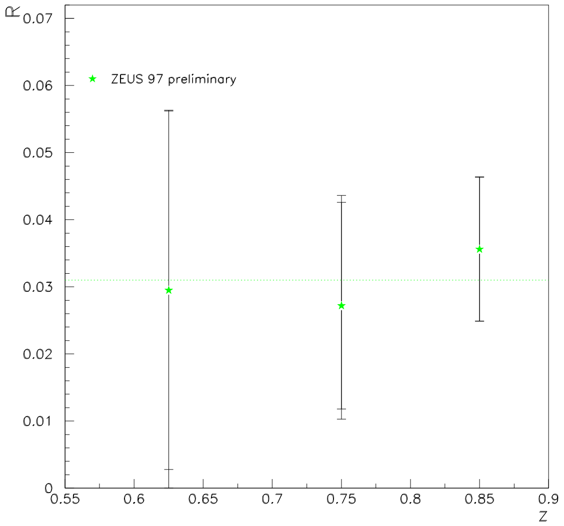


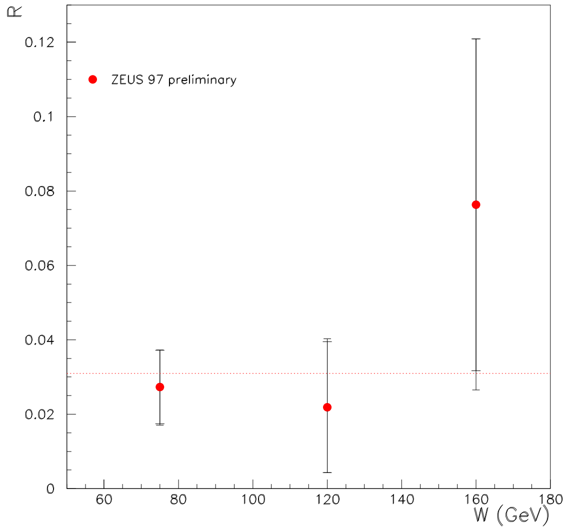
- resolved photon processes relevant mainly at high $W_{\gamma p}$
- different $W_{\gamma p}$ dependences for direct and resolved component

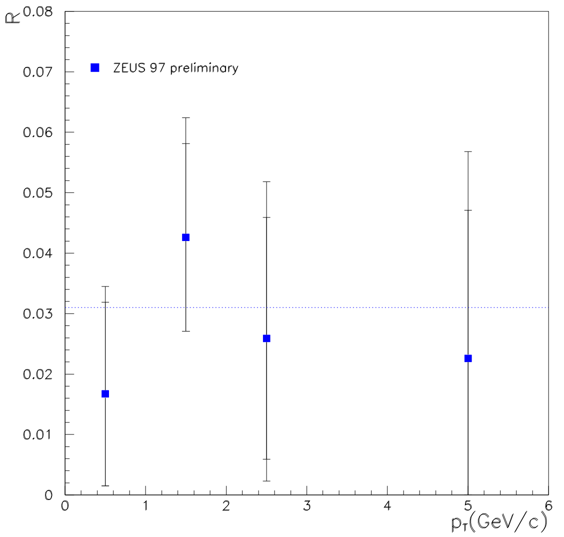
$\Rightarrow$ extrapolation in $W_{\gamma p}$ difficult


H1 prelim.
0.3 < z < 0.8
direct BGF MC
k=2
10 2
10
60
80
100
120
140
160
180
200
220
240

inelastic ψ' photoproduction







measured:

$$R = \frac{B_{\psi'}\,\sigma_{\psi'}}{B_{J/\psi}\,\sigma_{J/\psi}}$$

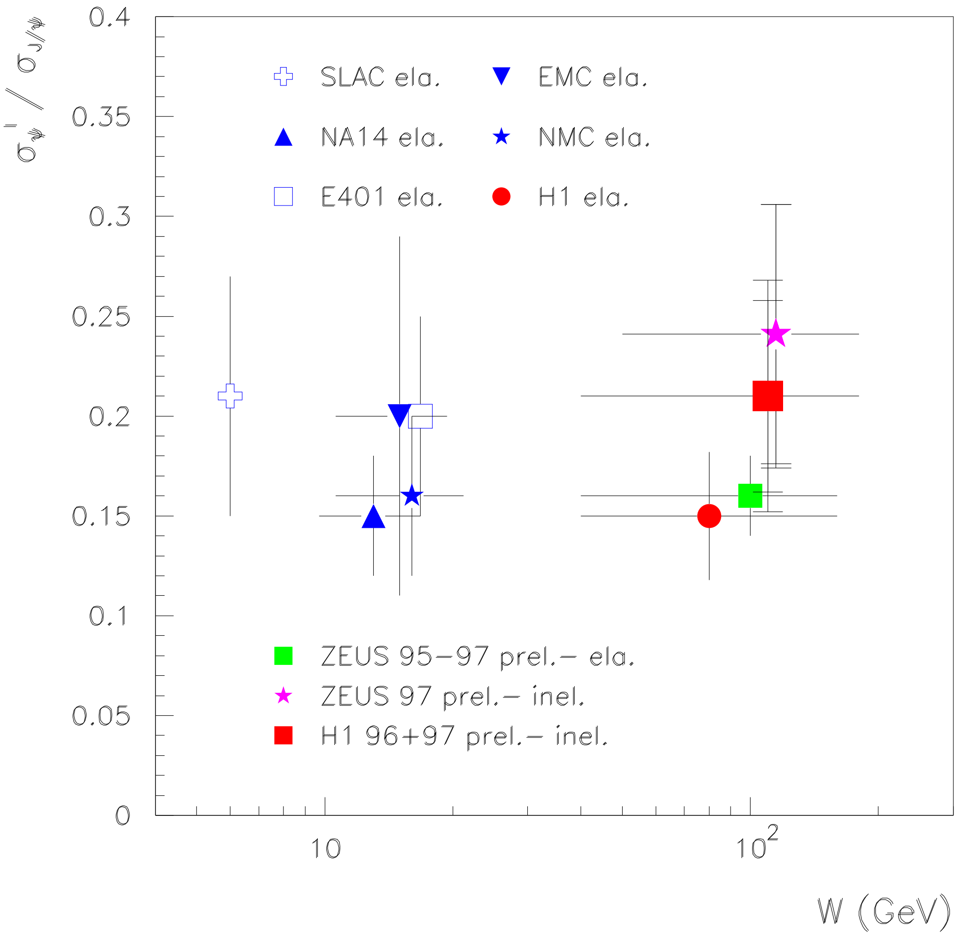
- expectation at LO for direct photon gluon fusion in the CSM:

$$\frac{\sigma_{\psi'}}{\sigma_{J/\psi}} = \left(\frac{m_{J/\psi}}{m_{\psi'}}\right)^3 \cdot \frac{\Gamma_{\psi' \to l^+ l^-}}{\Gamma_{J/\psi \to l^+ l^-}} = const.$$

$$R = \frac{B_{\psi'}\,\sigma_{\psi'}}{B_{J/\psi}\,\sigma_{J/\psi}} = 0.031$$

$\Rightarrow$ within the present statistics data agree with LO CSM

inelastic ψ' photoproduction



- error due to the uncertainty of $\Gamma_{\psi' \to l^+ l^-}$ not included

$\Rightarrow$ within the present statistics the inelastic ratios are consistent with the elastic ones

conclusions and outlook

- J/ψ photoproduction at “medium“ z in good agreement with NLO calculations in the Colour Singlet Model

- new measurement in the “low“ z region shows contributions of resolved photon processes to the J/ψ production

- ratio of inelastic ψ' to J/ψ photoproduction in agreement with expectation in the CSM and with elastic photoproduction measurements

- present statistics and uncertainties on Colour Octet matrix elements don’t allow definite conclusion on CO contributions

$\Rightarrow$ data of 1998 and 1999 should be included

$\Rightarrow$ double differential cross sections could help to distinguish CS and CO contributions