

Inelastic J/ψ Production at H1

Karin Daum - Wuppertal/DESY
on behalf of

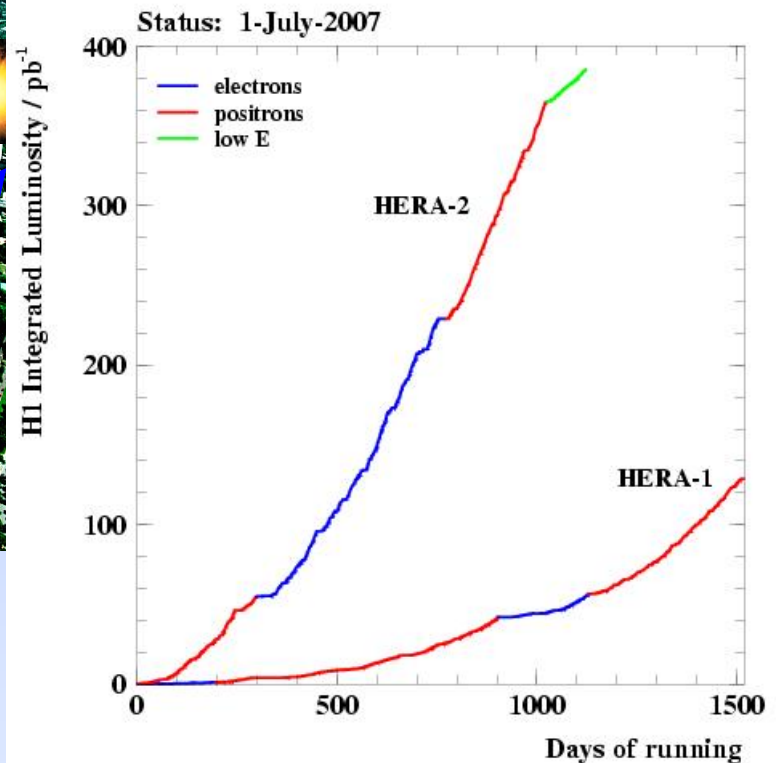
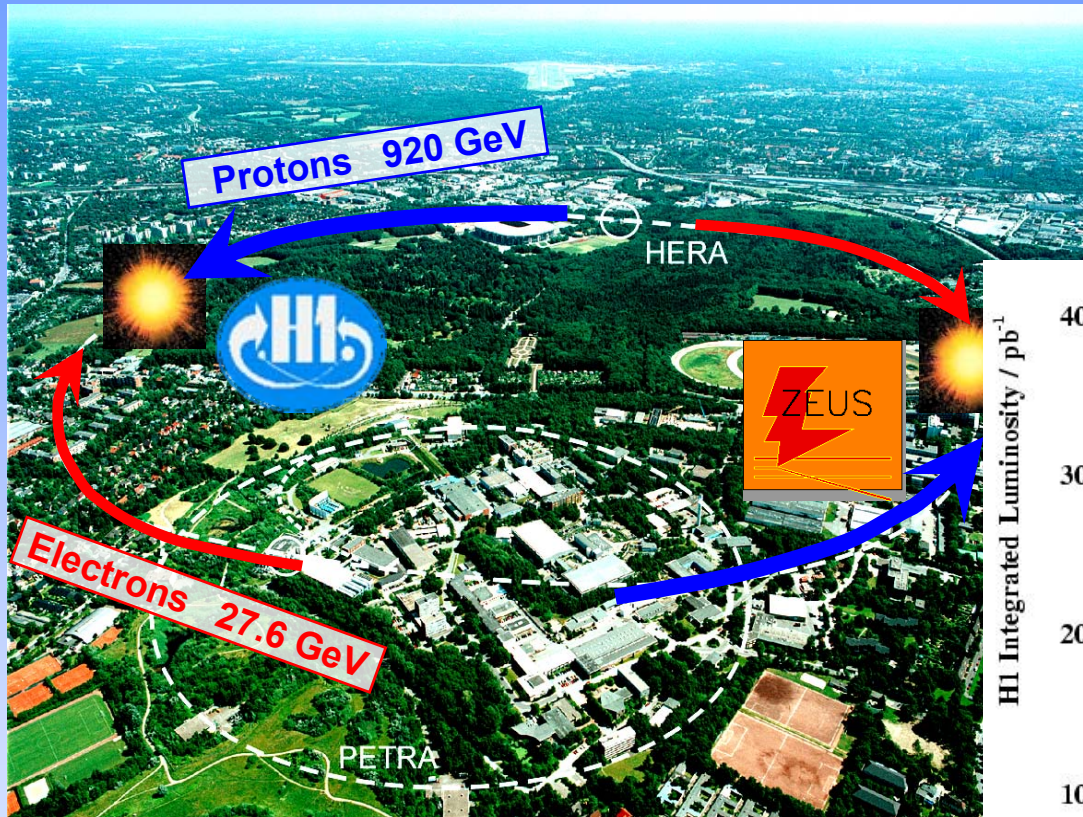


Outline:

- HERA & kinematics at HERA
- Theory & Monte Carlo models
- Data selection and data samples
- Inelastic J/ψ production cross sections in DIS and γp
- Conclusions

The HERA accelerator

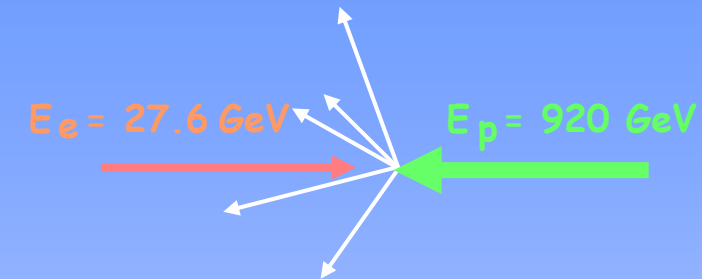
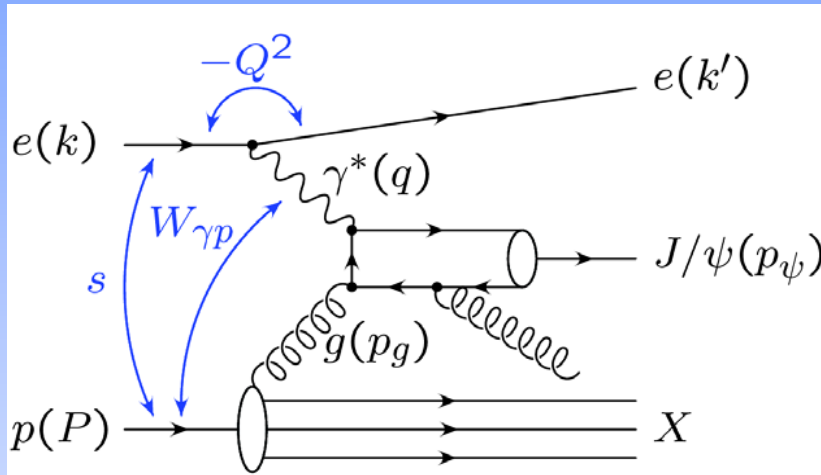
DESY
Hamburg-Germany



integrated luminosity
HERA I 120 pb^{-1}
 \Rightarrow HERA II 360 pb^{-1}

Charm Production at HERA

Boson-Gluon-Fusion
 $\gamma g \rightarrow c\bar{c}$



ep-Kinematics:

$$s = (P + k)^2$$

$$Q^2 = -q^2$$

$$W_{\gamma p} = (P + q)^2$$

$$z_{J/\psi} = \frac{p_{\psi} \cdot P}{q \cdot P} = \frac{E_{\psi}^*}{E_{\gamma}^*}$$

Proton
rest frame

2 kinematic regimes :

$Q^2 \cong 0 \text{ GeV}^2$: **Photoproduction (γp)**

$Q^2 > 3.6 \text{ GeV}^2$: **Electroproduction (DIS)**

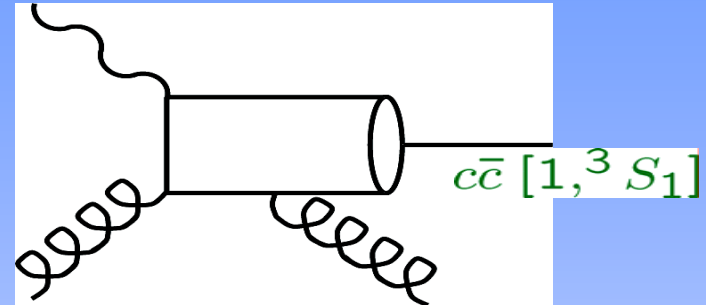
Inelastic J/ψ Production

Color Singlet Model (CS)

- radiation of a hard gluon
- $\sigma(J/\psi)$ determined by $|R_\psi(0)|$ as obtained from $\Gamma(J/\psi \rightarrow l^+l^-)$

LO: Berger et al, Baier et al, 1981

NLO (direct): Krämer et al, 1995



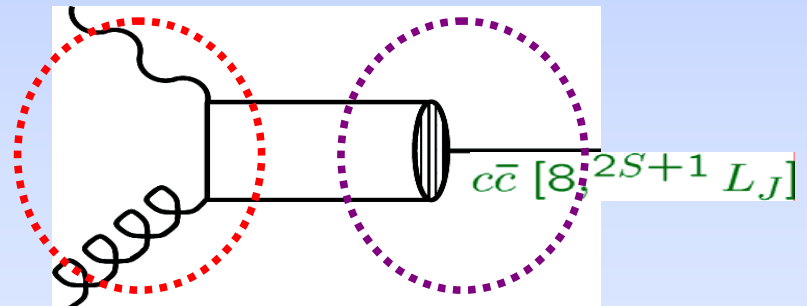
Factorization Ansatz in NRQCD

Color Octet Model (CO)

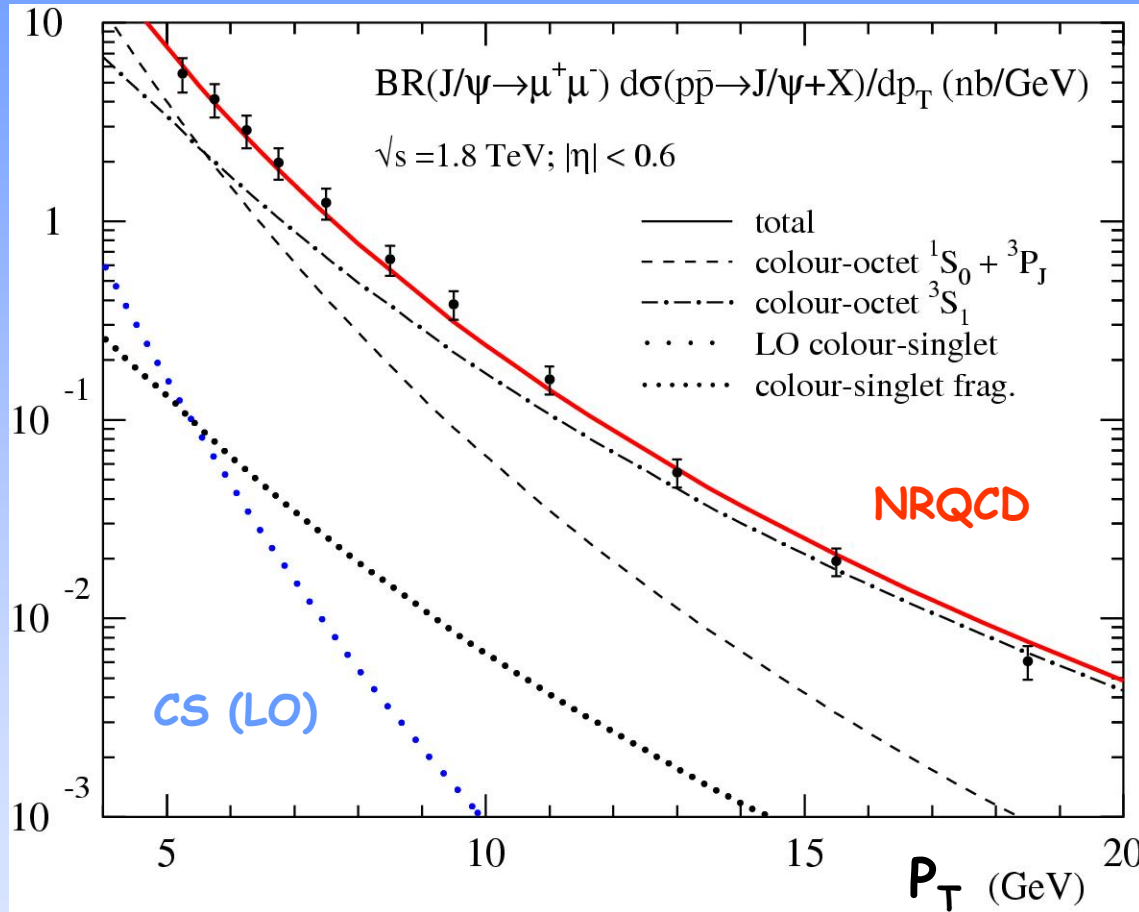
- initial quantum number of $c\bar{c}$ -pair may differ from J/ψ
- soft gluon emission
- non-perturbative LDME extracted from Tevatron data

Bodwin, Braaten, Lepage, 1995

$$\sigma_{J/\psi X} = \sum \hat{\sigma}(p\bar{p} \rightarrow c\bar{c}[n]X) \times \text{LDME}[n]$$



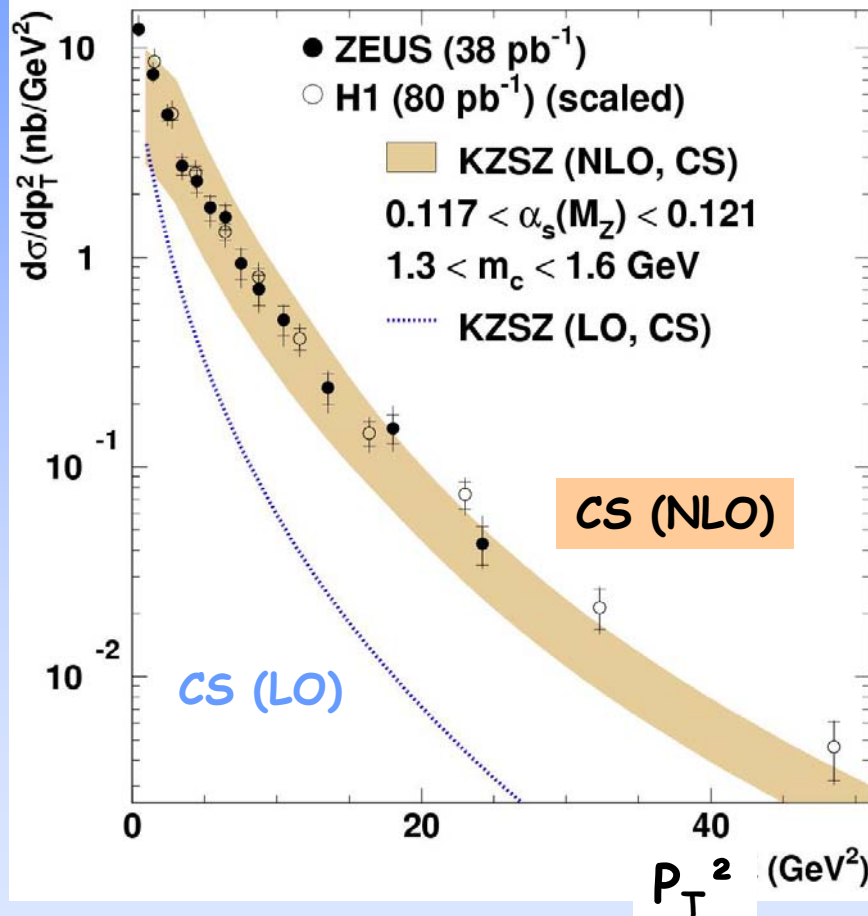
Hadroproduction of J/ψ @ TEVATRON



- CS LO:
much too low

- NRQCD (CO)
fits these data

Photoproduction of J/ψ @ HERA



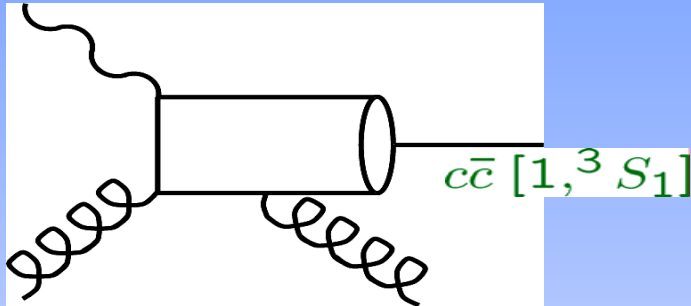
- CS LO: much too low at large p_T^2 (similar to hadroproduction)

- CS NLO agrees with data in normalization & shape

⇒ no need for large Color octet contributions

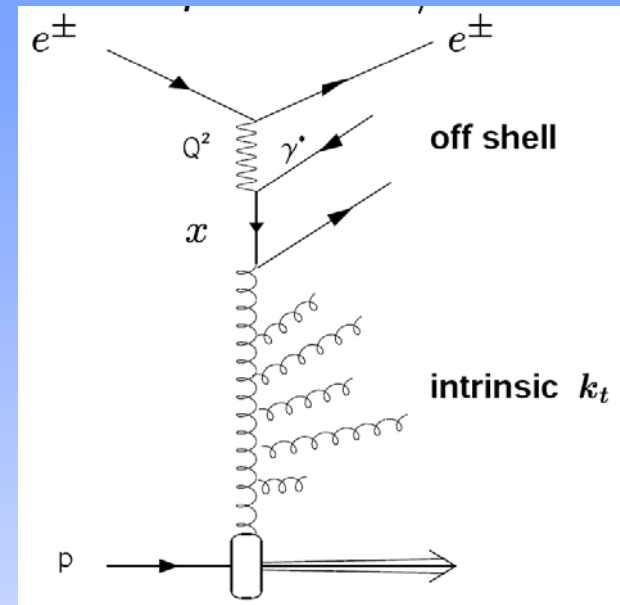
Monte Carlo Model

EPJPSI V3.3



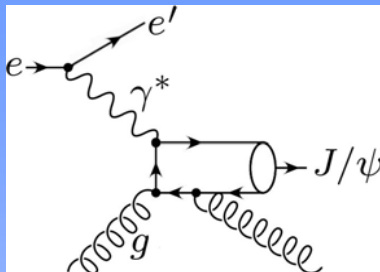
- J/ψ via LO color singlet
- DGLAP evolution equations (collinear factorization)
- on-shell matrix element
- applicable to γp and DIS

CASCADE V2.0



- J/ψ via LO color singlet
- CCFM evolution equations (k_{\perp} factorization)
- ISR to all orders
- off-shell matrix element
- applicable to γp and DIS

Data Samples



Data as of DIS07
new
model predictions

Electroproduction (DIS)

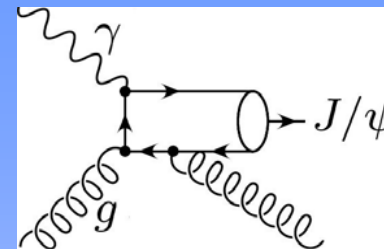
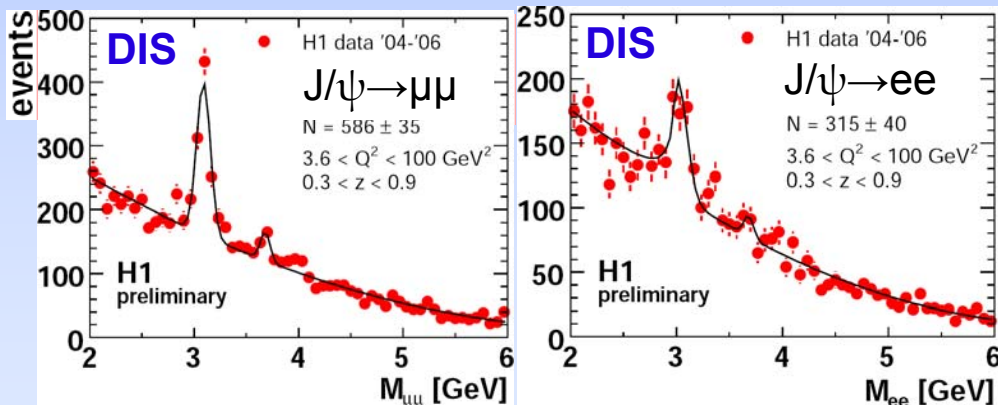
$\mathcal{L} \approx 258 \text{ pb}^{-1}$ (2004-2006)

$3.6 < Q^2 < 100 \text{ GeV}^2$

$50 < W_{\gamma p} < 225 \text{ GeV}$

$P_{T,\psi}^* > 1.0 \text{ GeV}$ (P_T in γp rest frame)

$0.3 < z_{J/\psi} < 0.9$



Photoproduction (γp)

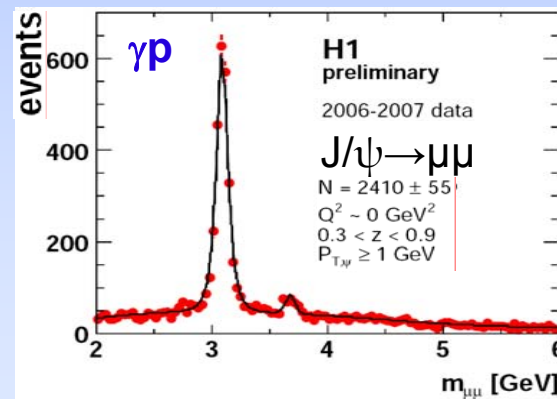
$\mathcal{L} \approx 166 \text{ pb}^{-1}$ (2006-2007)

$Q^2 \sim 0 \text{ GeV}^2$

$60 < W_{\gamma p} < 240 \text{ GeV}$

$P_{T,\psi} > 1.0 \text{ GeV}$

$0.3 < z_{J/\psi} < 0.9$



Backgrounds from Indirect J/ψ Production

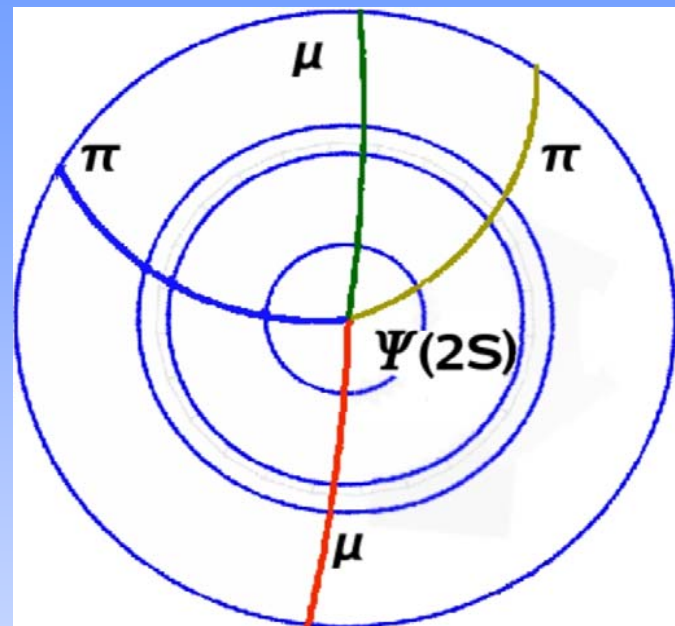
- **Diffraction $\psi(2S)$**

- $\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$ (BR $\sim 30\%$)
- high z region ($z \sim 0.85$)
- suppressed by $N_{ch} \geq 5$ requirement
- remaining contribution:
 - overall: $\sim 1.5\%$
 - highest z bin: $< 5\%$

- **Inelastic $\psi(2S)$ included**

- **B meson decays**

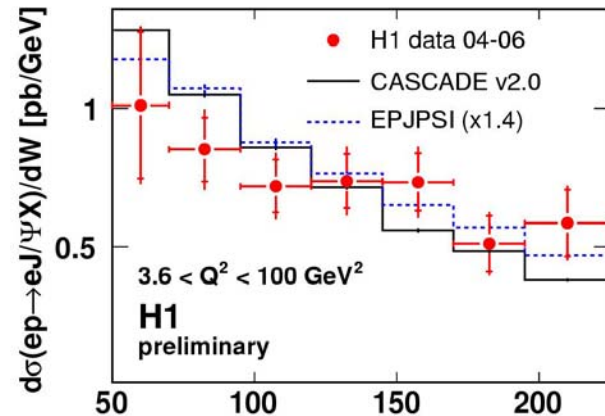
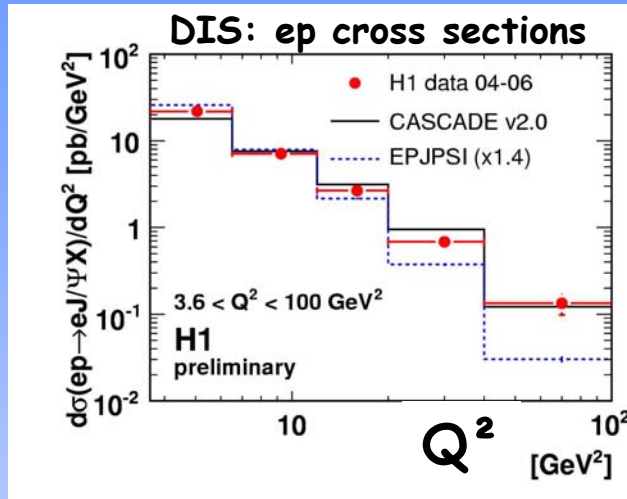
- low z region
- high track multiplicity, larger $P_T(J/\psi)$
- contribution:
 - overall: $\sim 2.5\%$
 - lowest z bin: $< 10\%$



Not subtracted from cross sections

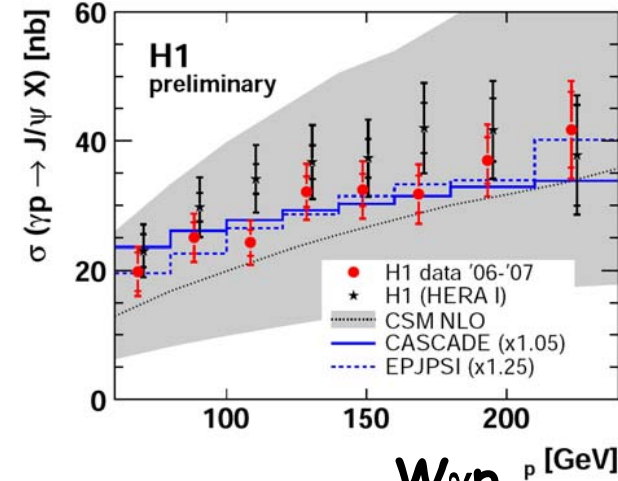
Cross Sections vs. Q^2 and $W_{\gamma p}$

DIS



DIS

- HERA-II agrees with HERA-I significantly reduced errors
- **CS NLO** calc. agree with γp data but large scale uncertainties
- Data well described by CS model as implemented in **CASCADE**
- **CS LO (EPJPSI)** agree in shape of $W_{\gamma p}$ but off in normalization wrong Q^2 dependence

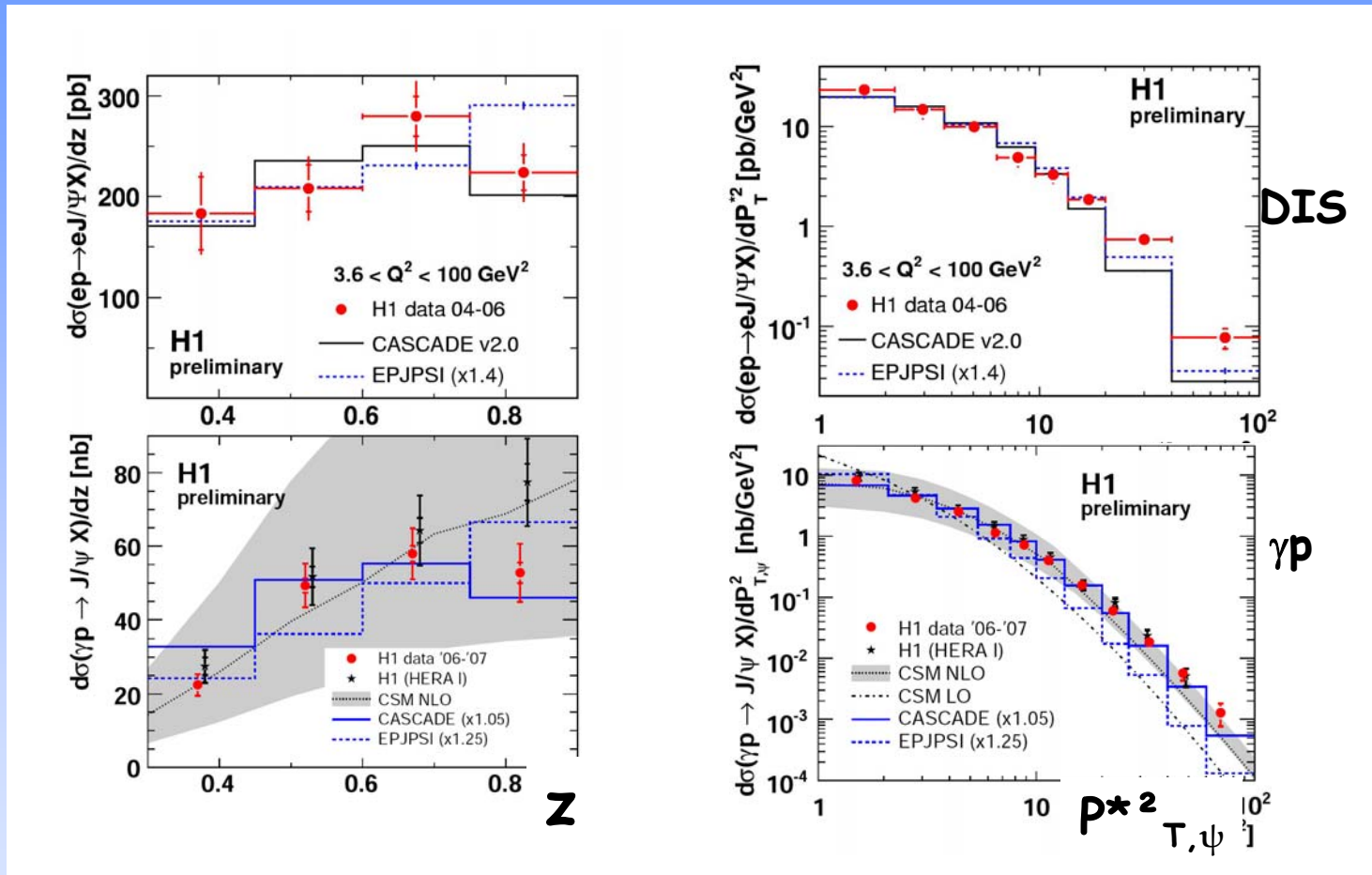


γp

γp : γp cross sections

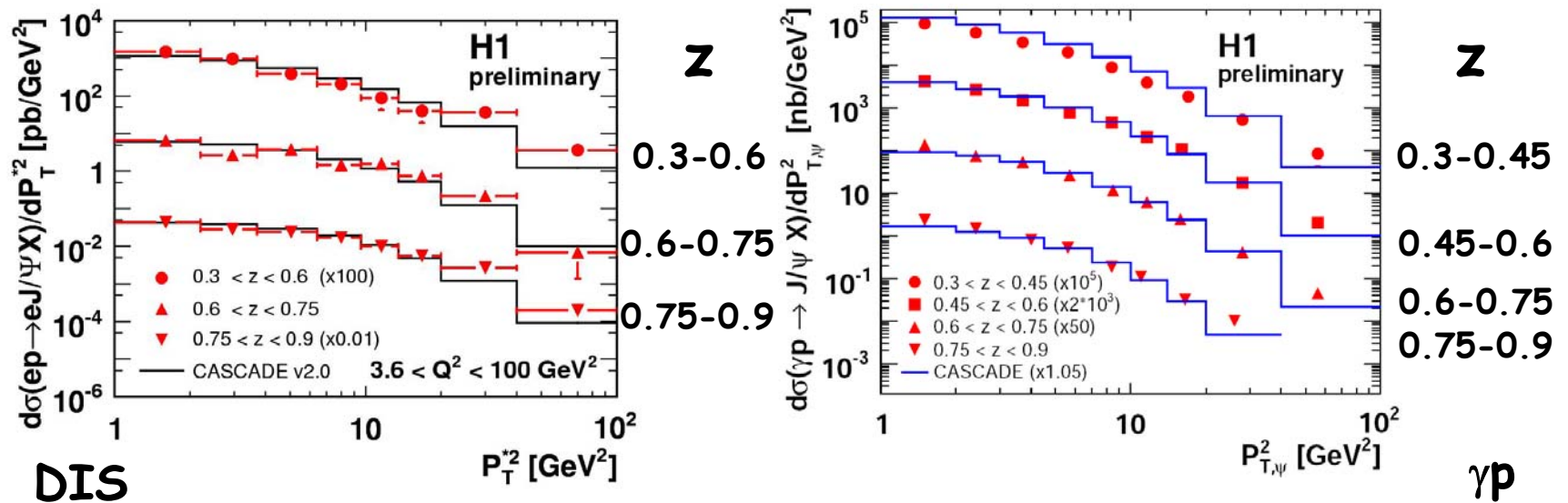
$W_{\gamma p}$ [GeV]

Cross Sections vs. $z_{J/\psi}$ and $P_{T,\psi}^2$



- **CS NLO** agree with γp data - uncertainties smaller at large $P_{T,\psi}^2$
- J/ψ kinematics also well described by **CASCADE**

Double Differential Cross Sections in (P_T^2, z)



J/ψ kinematics well described by the CS model in CASCADE in almost all details

Conclusions

- Preliminary results on inelastic J/ψ production from HERA-II in DIS and γp have been presented
 - new data are consistent with HERA-I results
 - significant improvements in precision
- NLO CS calculations in the collinear approach describe γp data, however with large scale uncertainties
- The CS model in the CCFM framework (CASCADE) describes the DIS and γp data nicely in normalization and shape almost everywhere
- The data do not show any need for additional “color octet” contributions in the phase space explored in DIS and γp