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Inelastic J/ψ Production at H1

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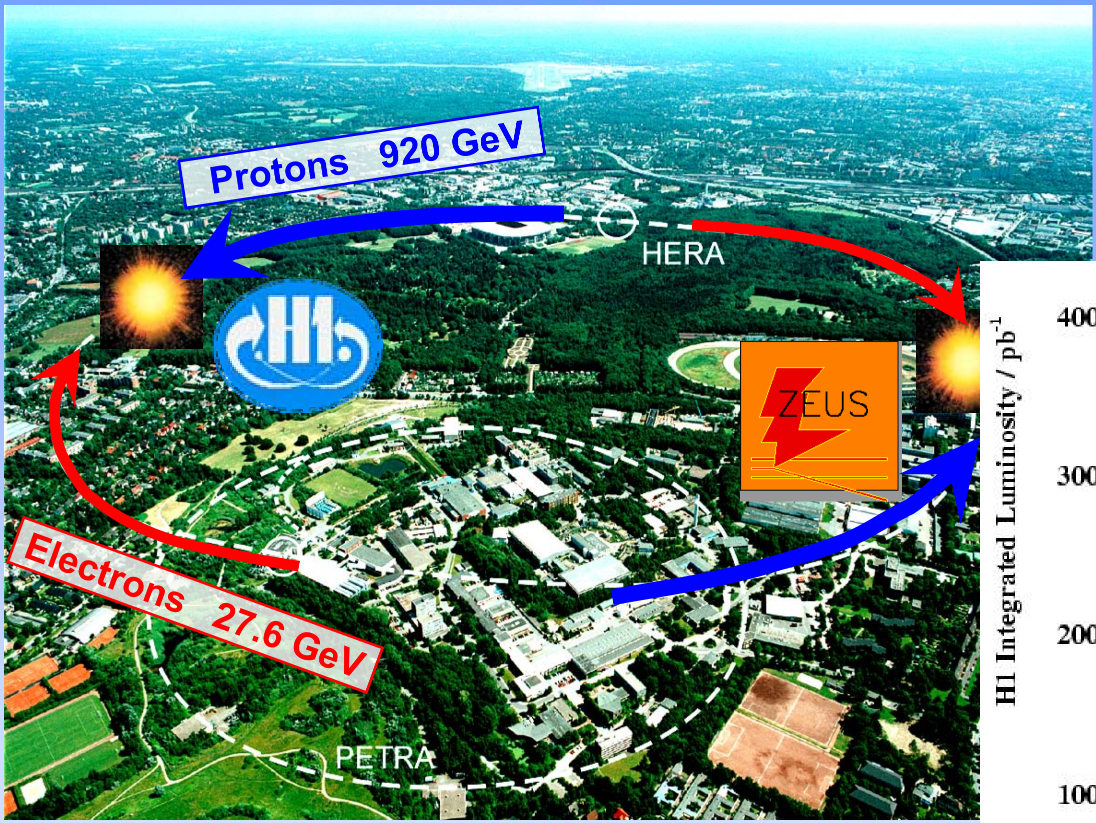
on behalf of

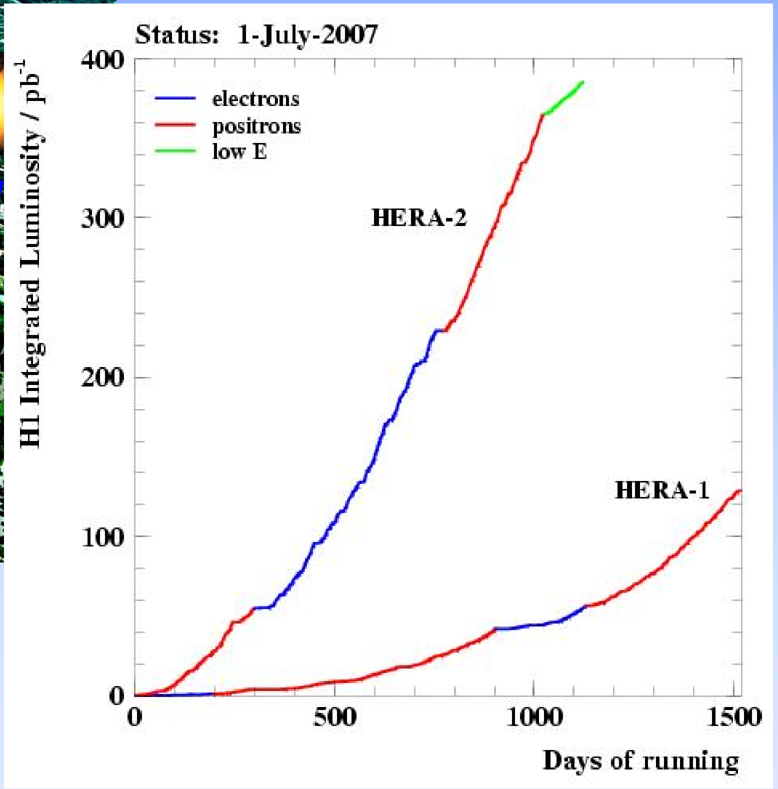
Outline:

- 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

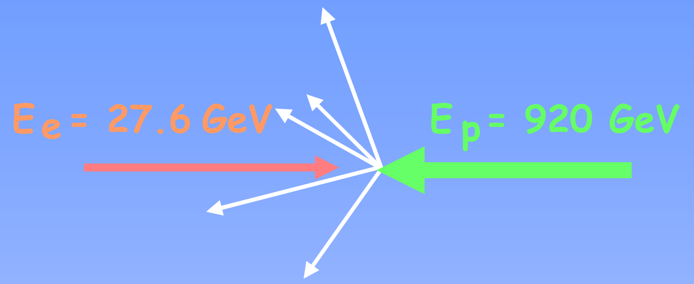


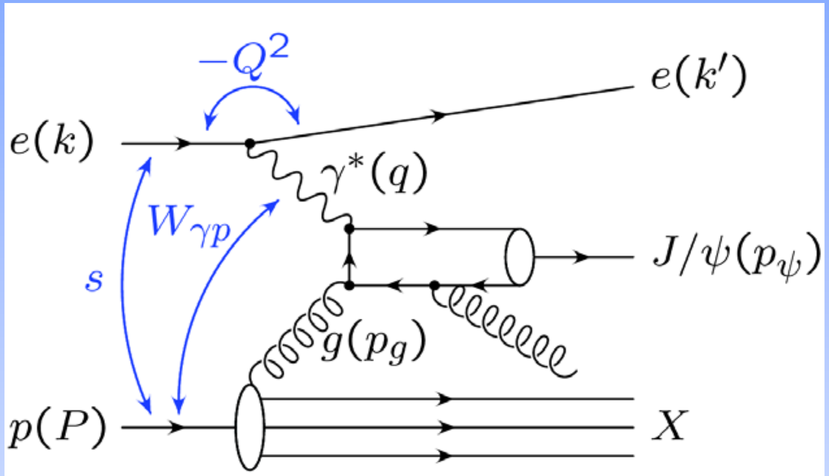
integrated luminosity

HERA I	120 pb^{-1}
⇒ HERA II	360 pb^{-1}

Charm Production at HERA

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





ep-Kinematics:

$s = (P + k)^2$

$Q^2 = -q^2$

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

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

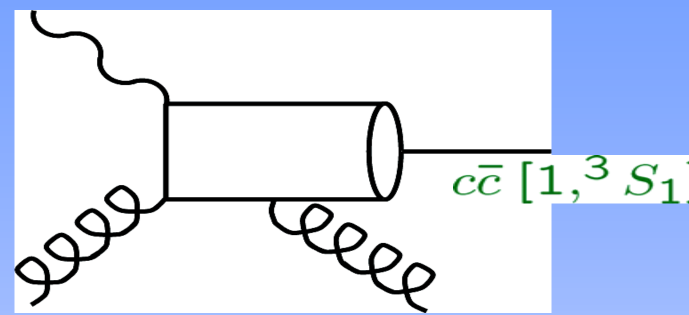
Proton rest frame

2 kinematic regimes :
$Q^2 \cong 0$ GeV^2 : **Photoproduction (γp)**
$Q^2 > 3.6$ 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

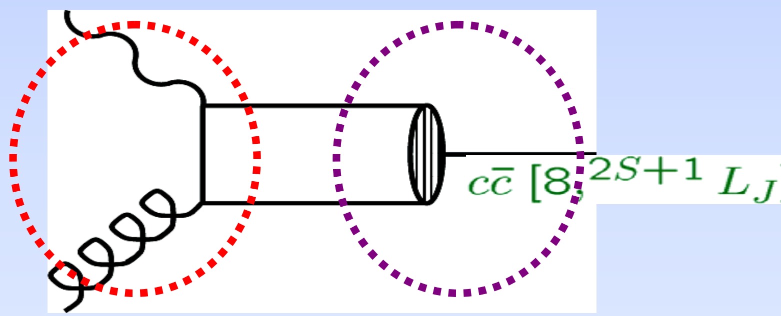
NLO (direct): Krämer et al, 1995

Factorization Ansatz in NRQCD

Color Octet Model (CO)

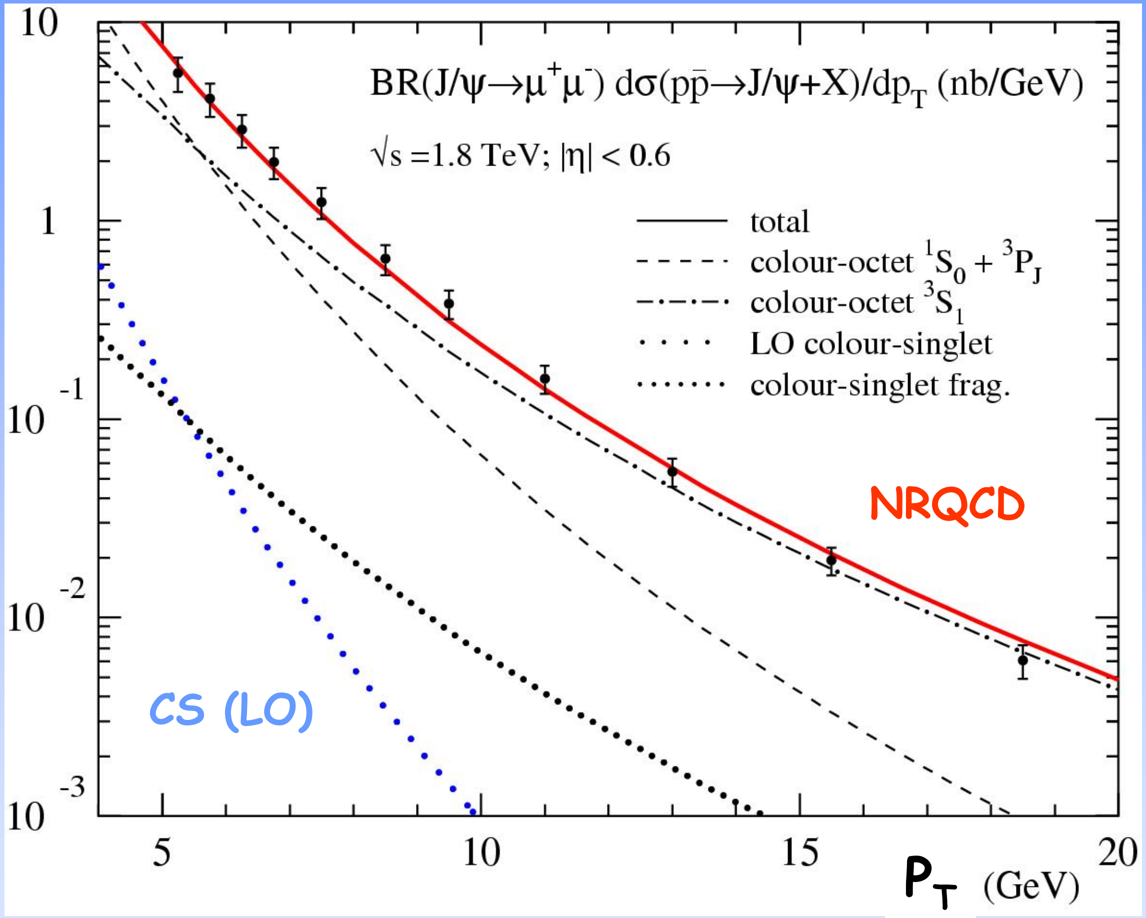
$$\sigma_{J/\psi X} = \sum \hat{\sigma}(p\bar{p} \rightarrow c\bar{c}[n]X) \times \mathrm{LDME}[n]$$

- initial quantum number of cc-pair may differ from J/ψ
- soft gluon emission
- non-perturbative LDME extracted from Tevatron data



Bodwin, Braaten, Lepage, 1995

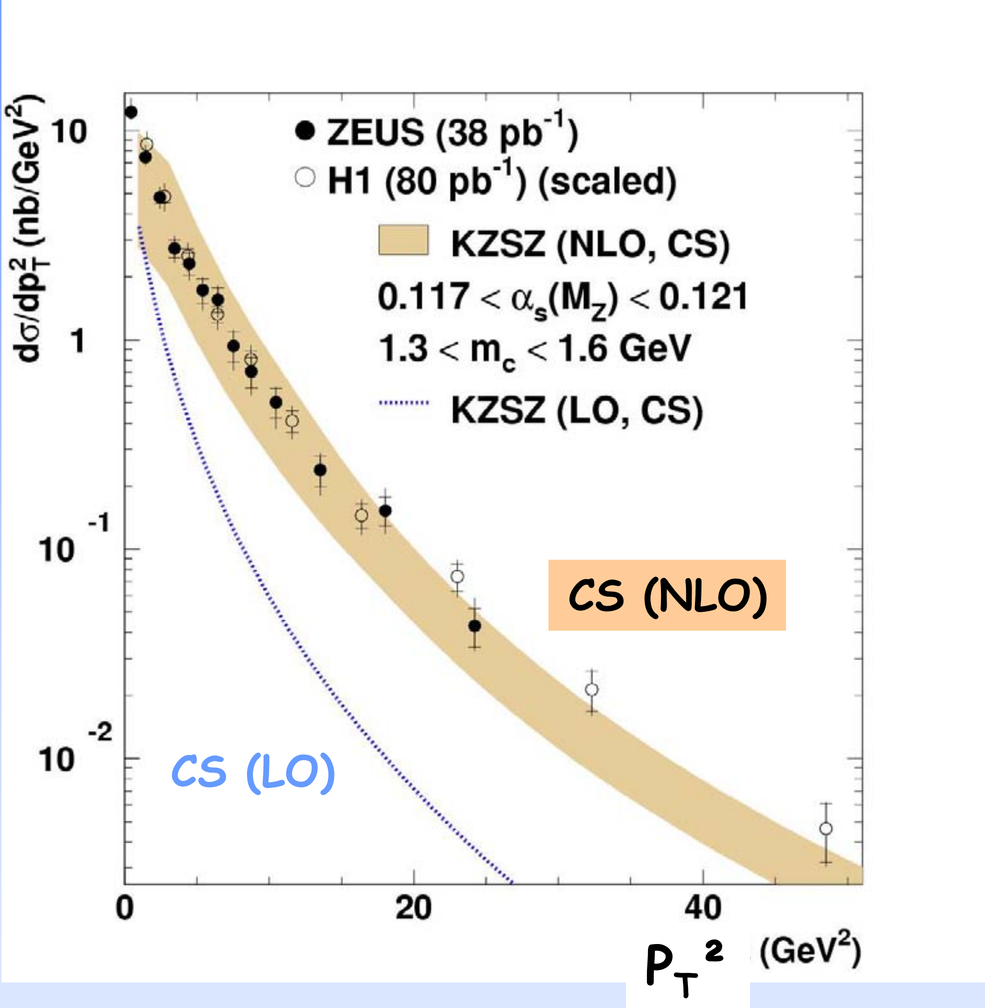
Hadroproduction of J/ψ @ TEVATRON



- ***CS LO:*** **much too low**

- **NRQCD (CO) fits these data**

Photoproduction of J/ψ @ HERA



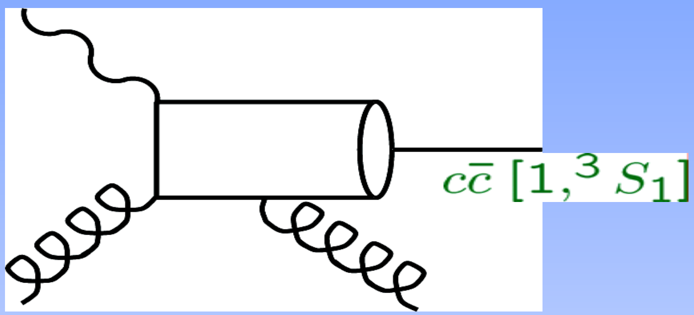
- CS LO: much too low at large P_T^2 (similar to hadroprodution)

- CS NLO agrees with data in normalization & shape

⇒ no need for large Color octet contributions

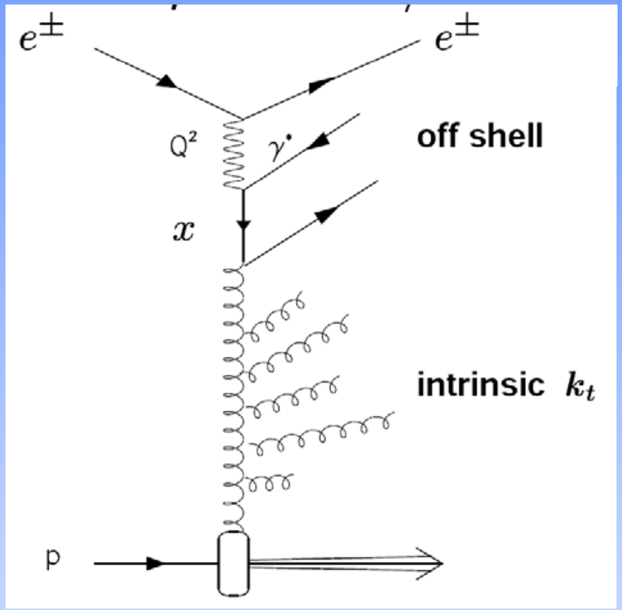
Monte Carlo Model

EPJPSI V3.3



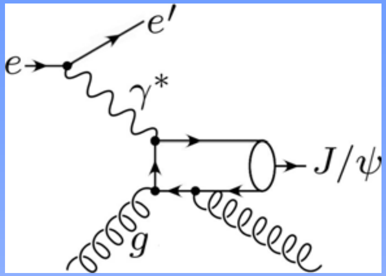
- J/ψ via LO color singlet
- DGLAP evolution equations (collinear factorization)
- on-shell matrix element
- applicable to γp and DIS

CASCADE V2.0



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

Data Samples



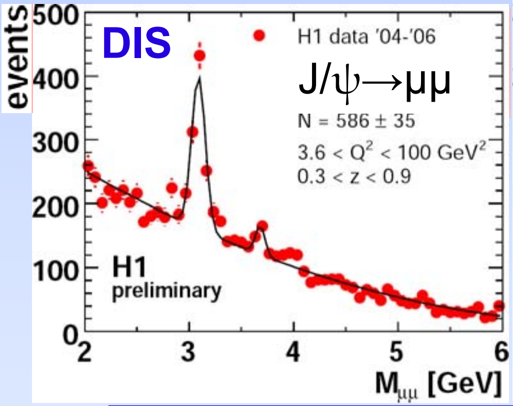
Data as of DIS07

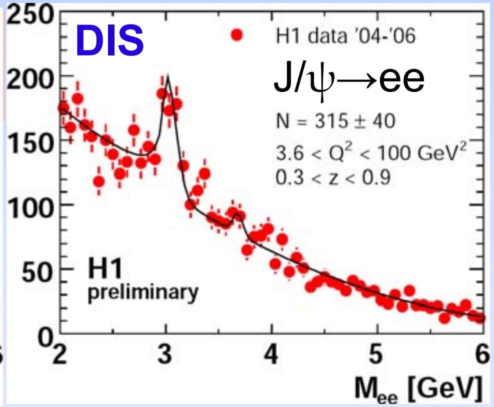
new
model predictions

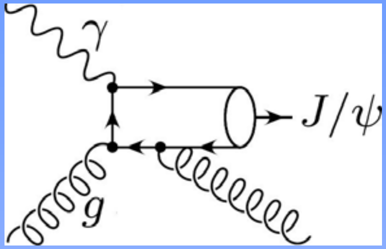
Electroproduction (DIS)

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

$3.6 < Q^2 < 100\ GeV^2$
$50 < W_{\gamma p} < 225\ GeV$
$P^*_{T,\psi} > 1.0\ GeV$ (P_T in γp rest frame)
$0.3 < z_{J/\psi} < 0.9$



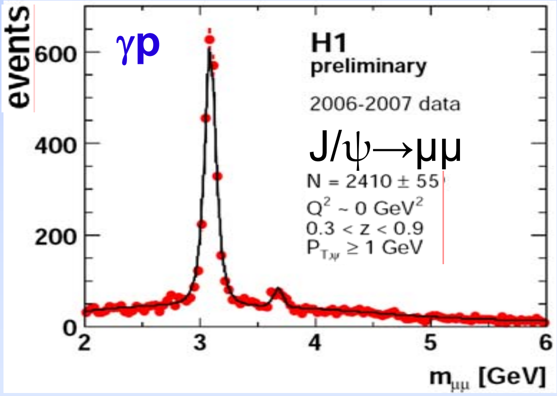




Photoproduction (γp)

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

$Q^2 \sim 0\ GeV^2$
$60 < W_{\gamma p} < 240\ GeV$
$P_{T,\psi} > 1.0\ GeV$
$0.3 < z_{J/\psi} < 0.9$

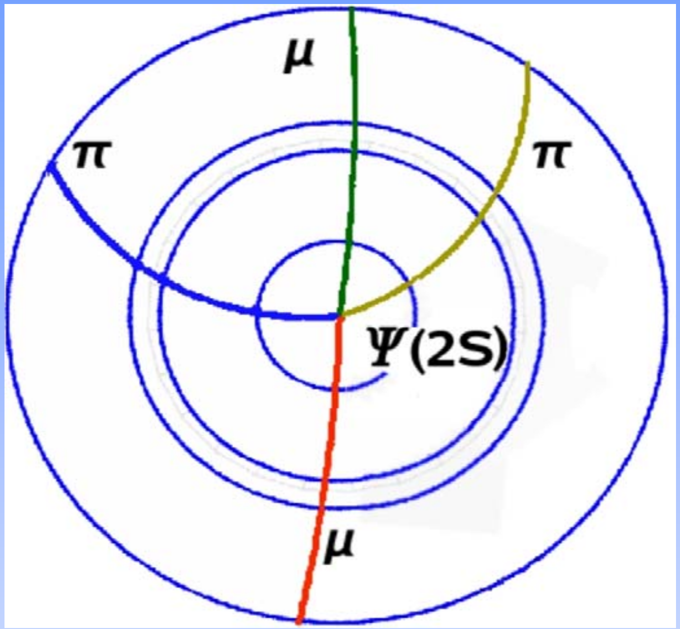


Backgrounds from Indirect J/ψ Production

- **Diffractive ψ(2S)**
  - ψ(2S) → J/ψ $\pi^+\pi^-$ (BR ~30%)
  - high z region (z ~ 0.85)

  → suppressed by $N_{ch} \geq 5$ requirement

  - remaining contribution:
    - overall: ~ 1.5%
    - highest z bin: < 5%



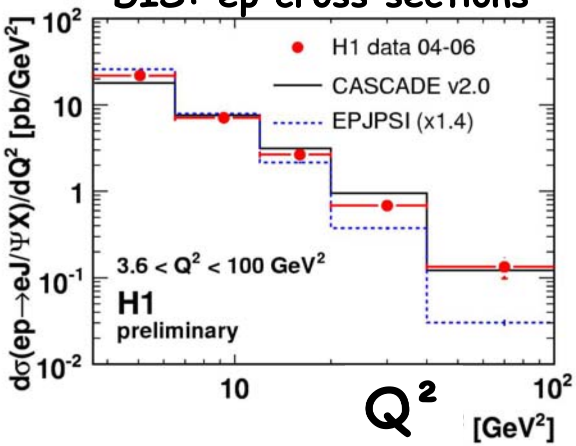
- **Inelastic ψ(2S) included**
- **B meson decays**
  - low z region
  - high track multiplicity, larger P_T(J/ψ)
  - contribution:
    - overall: ~ 2.5%
    - lowest z bin: < 10%

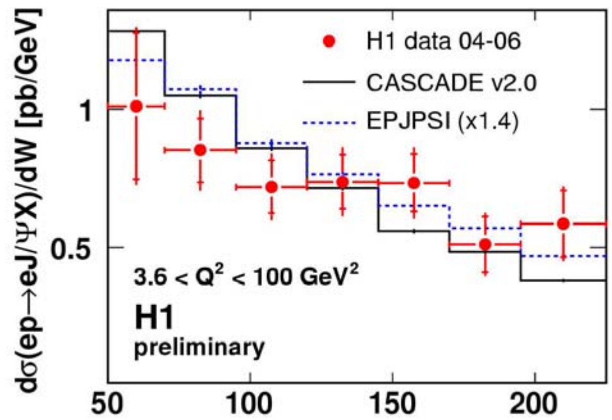
Not subtracted from cross sections

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

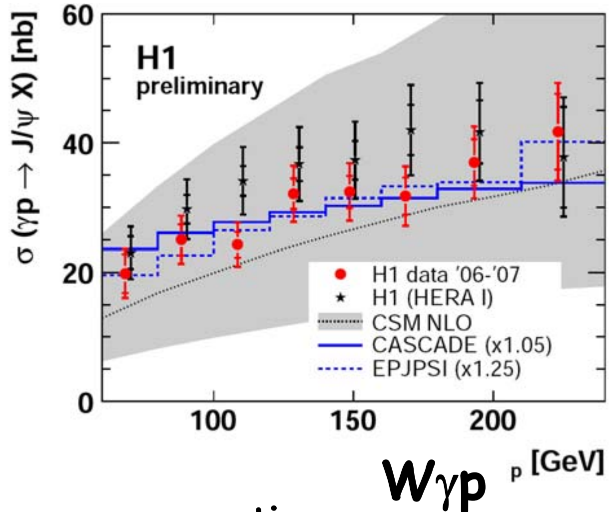
DIS: ep cross sections

DIS





DIS

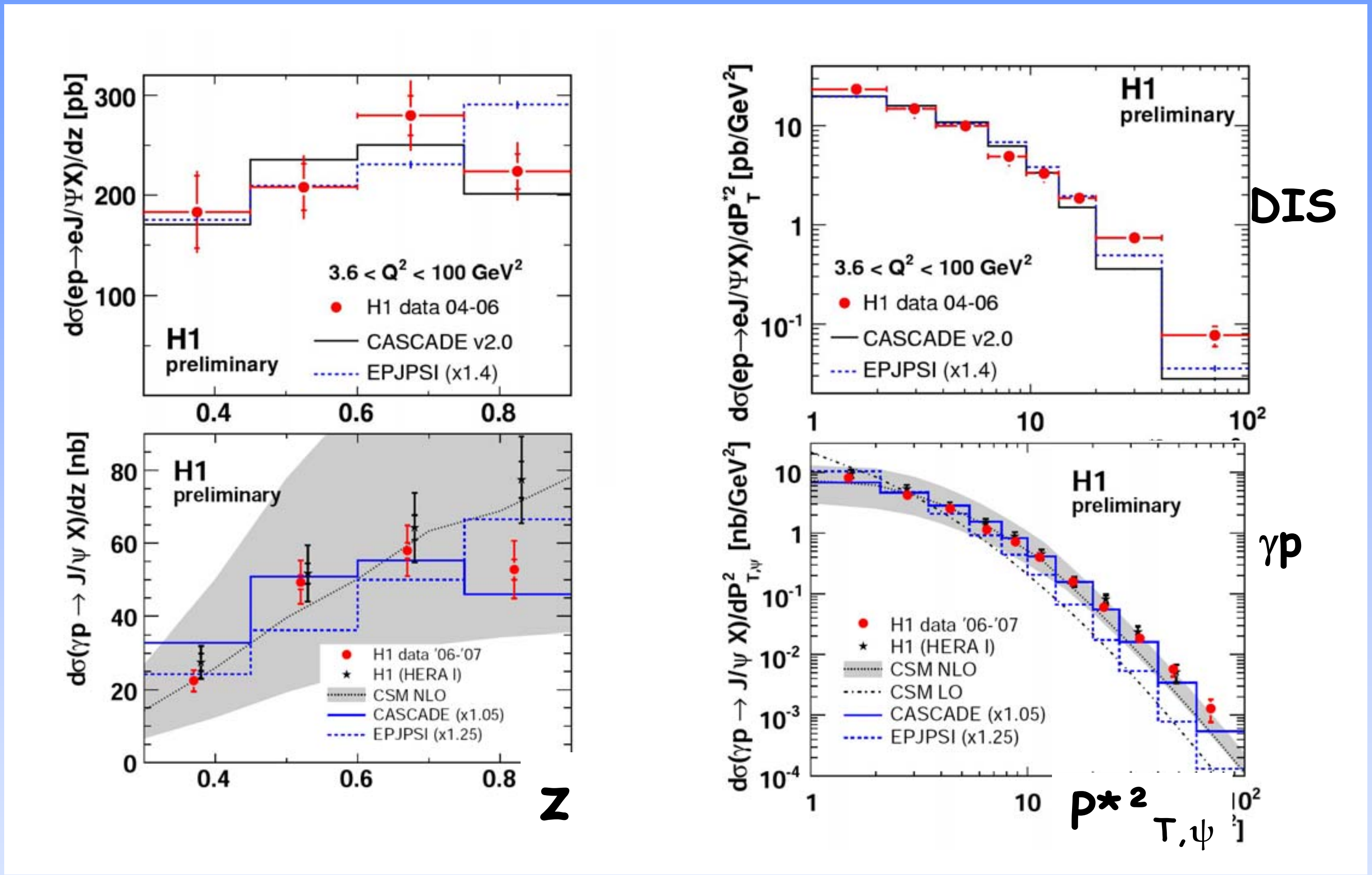


γp

γp: γp cross sections

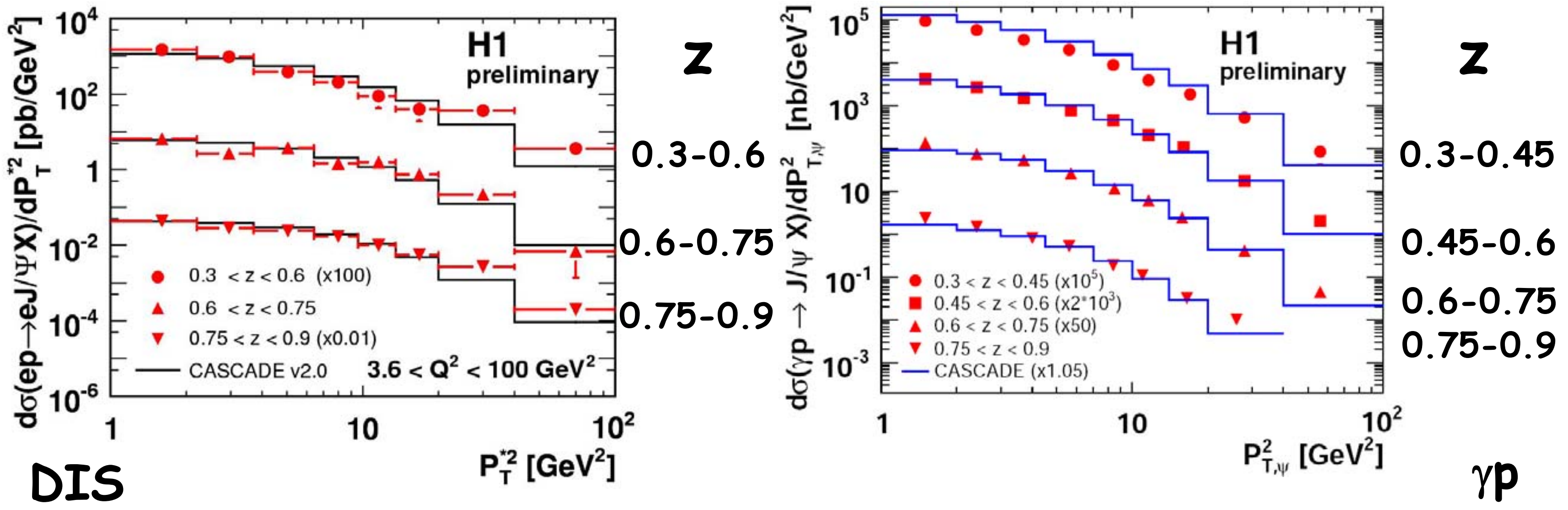
- HERA-II agrees with HERA-I significantly reduced errors
- CS NLO calc. agree with γp data but large scale uncertainties
- Data well described by CS model as implemented in CASCADE
- CS LO (EPJPSI) agree in shape of $W_{\gamma p}$ but off in normalization wrong Q^2 dependence

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



- **CS NLO** agree with γp data – uncertainties smaller at large $P^2_{T,\psi}$
- 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