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Production of Charmonia and Upsilon Mesons at HERA

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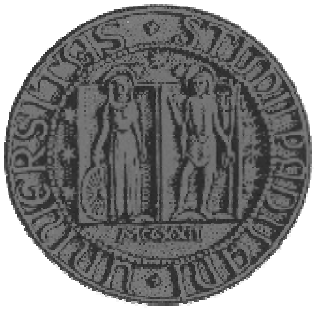
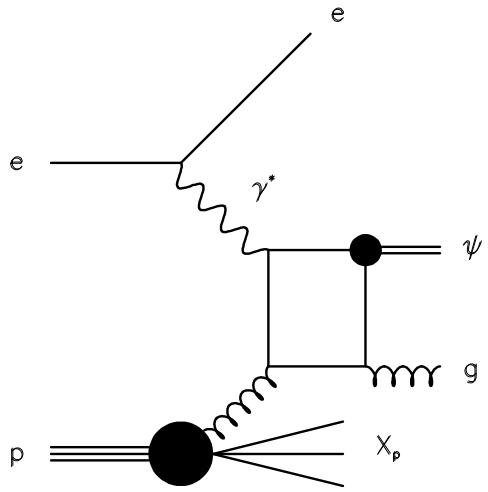
Outline:

- production processes and kinematic region
- inelastic charmonium (ψ and $\psi(2S)$)
- $\subseteq$ sector



Production processes

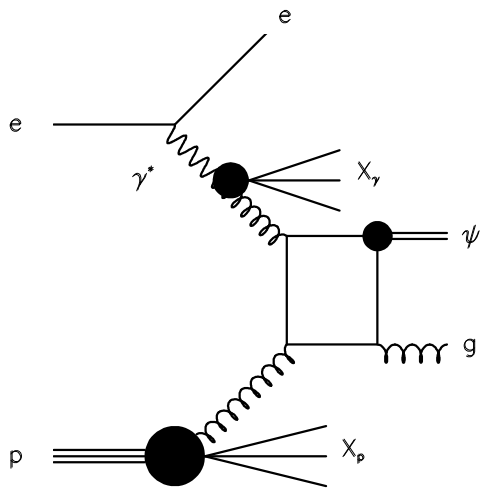
$$z = \frac{E_{J/\psi}}{E_{\gamma^*}} \ (p \text{ rest frame})$$



direct photon

color singlet model

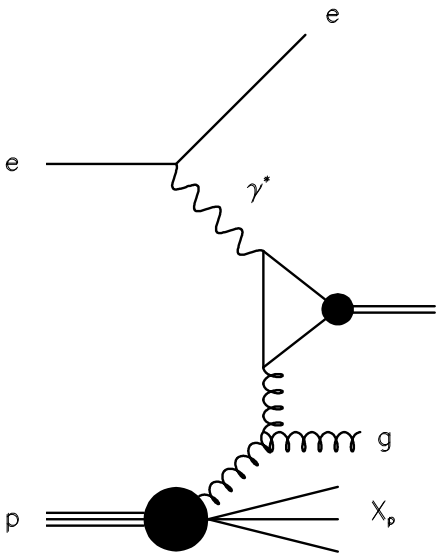
medium z



resolved photon

color singlet model

low z

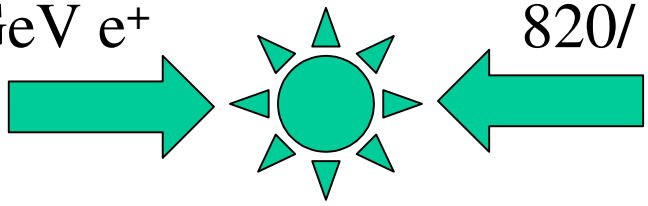


direct photon

color octet model

Kinematic region

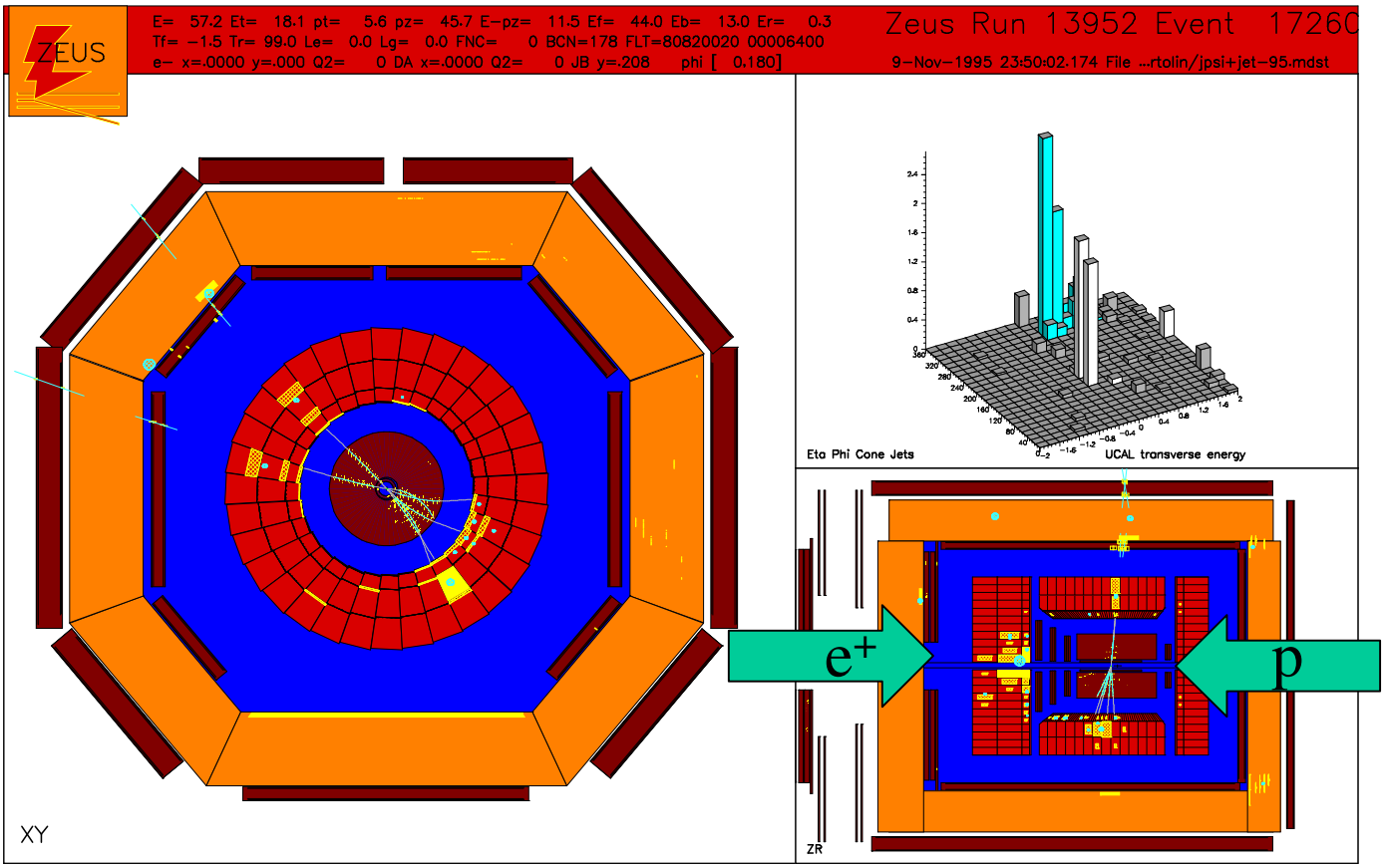
27.5 GeV e^+ 820/ 920 GeV p



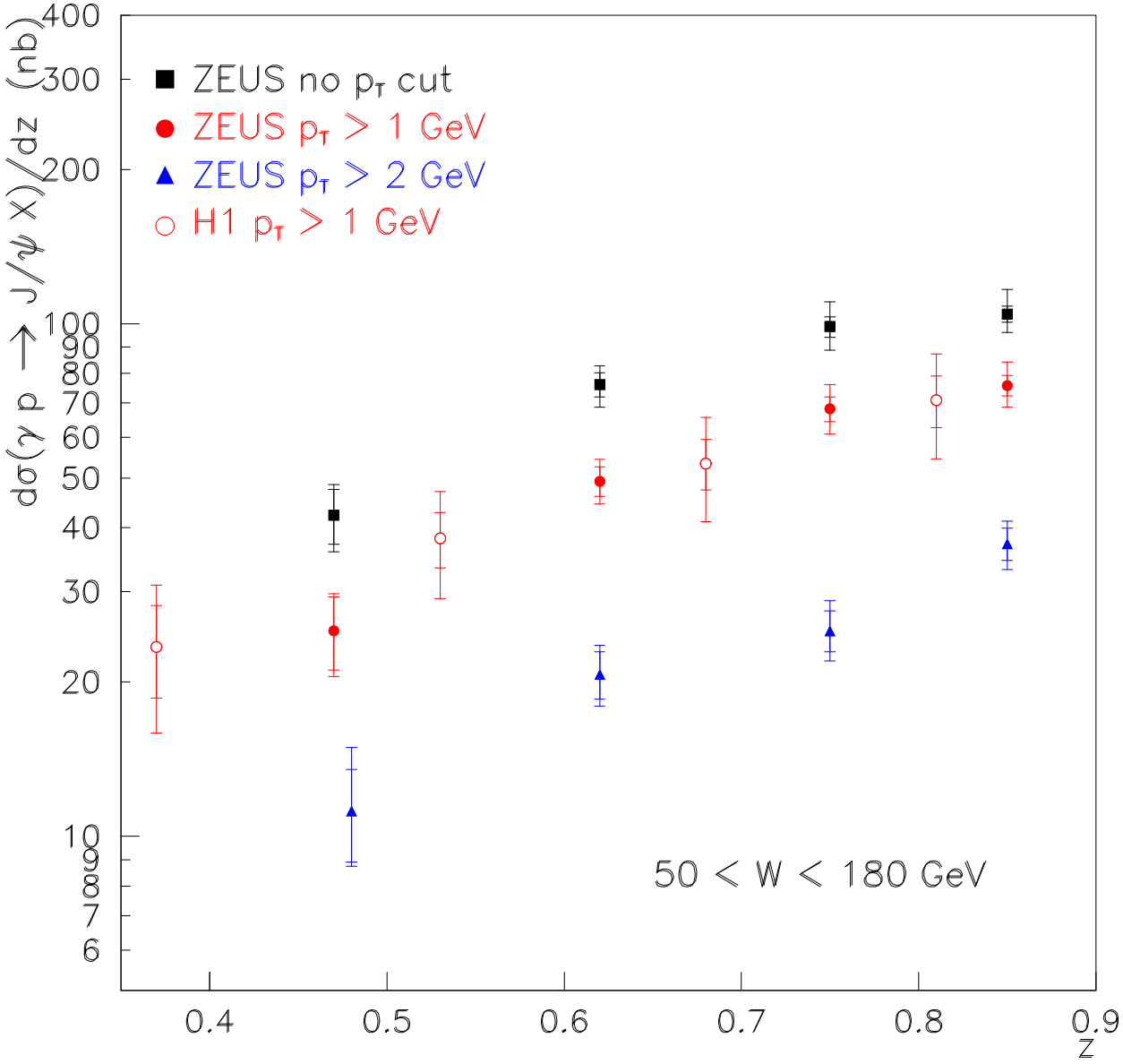
- $Q^2 < 1$ GeV^2 (photoproduction regime)
- wide $W_{\gamma p}$ coverage (30 – 270 GeV)

$$W_{\gamma p} = \sqrt{4 E_e E_p}\ \sqrt{y}$$

$$y = \frac{E_{\gamma^*}}{E_e}\ (p \text{ rest frame})$$

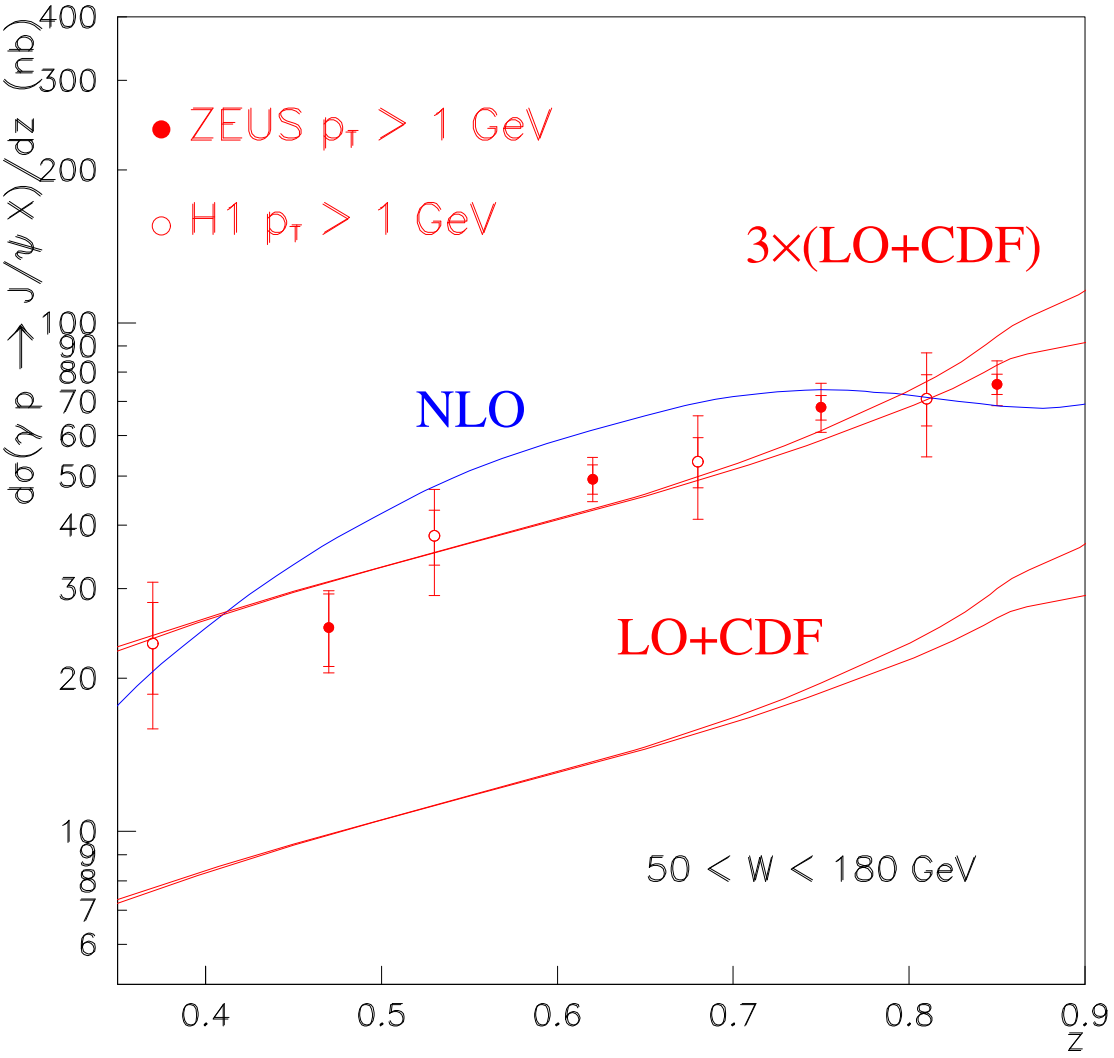


ZEUS 1996-97 Preliminary



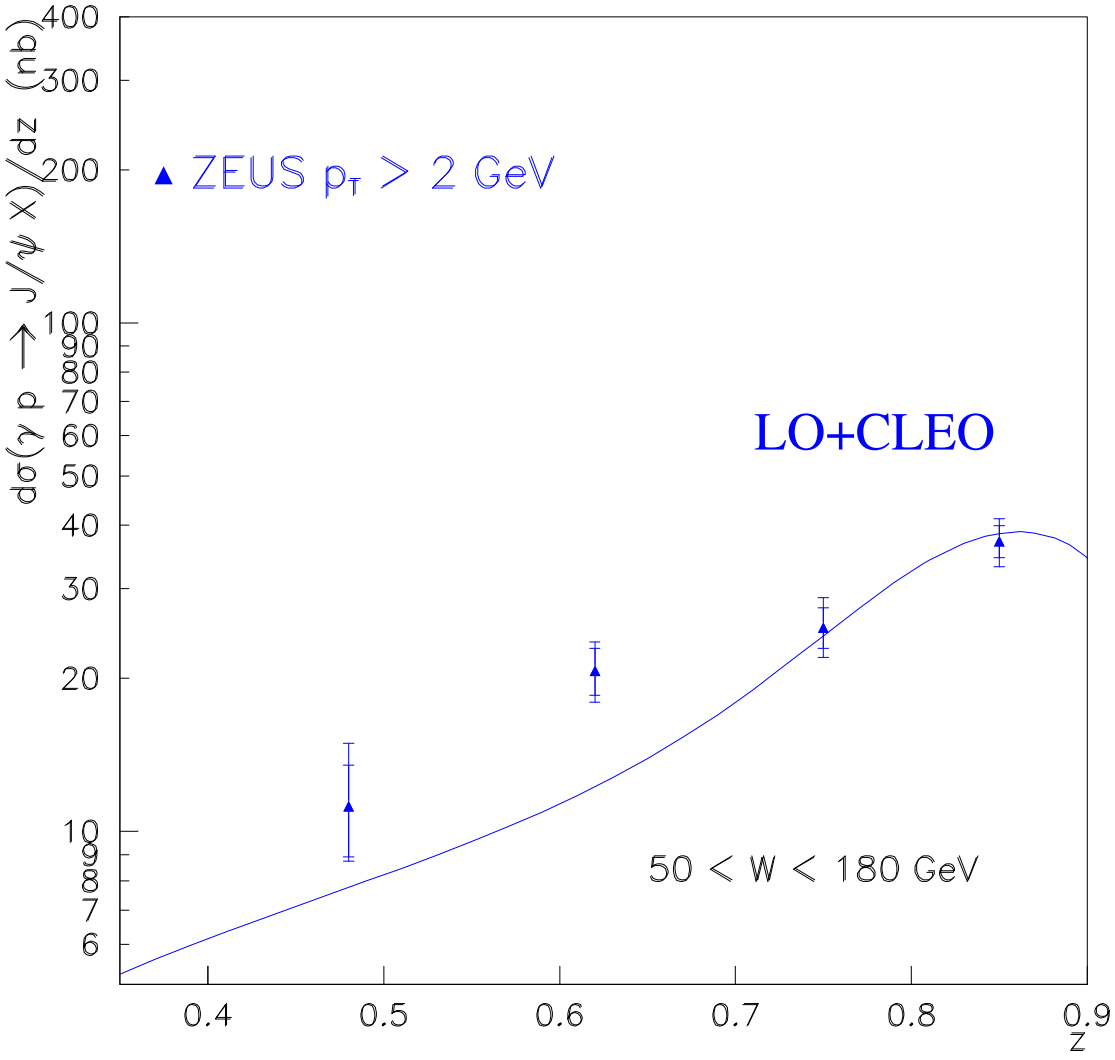
- similar shape for p_T>1 GeV and no p_T cut

Inelastic Ψ



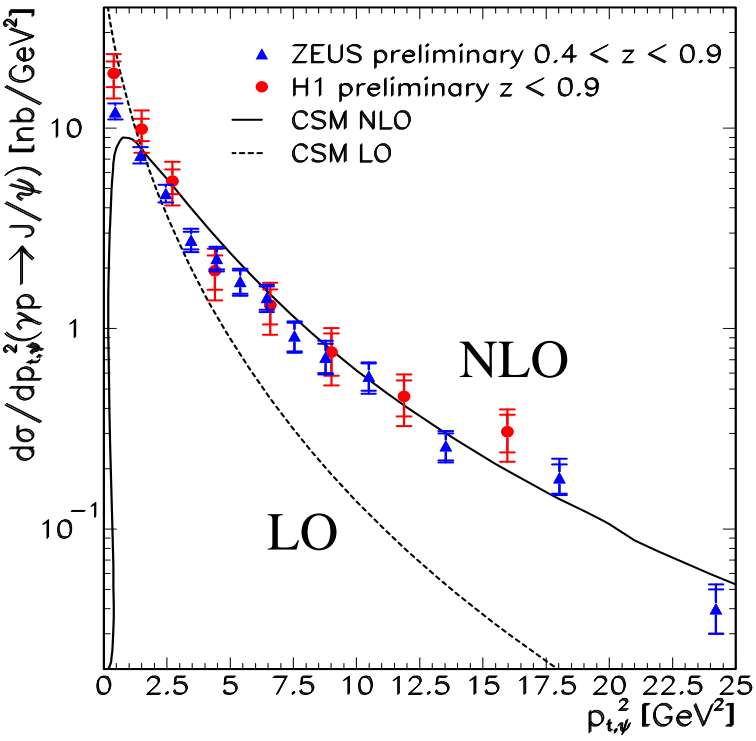
- color singlet + octet with CDF octet matrix elements: undershoots data but shape is fine
- byproduct: sensitive to the direct color singlet process
- NLO direct color singlet: fine !

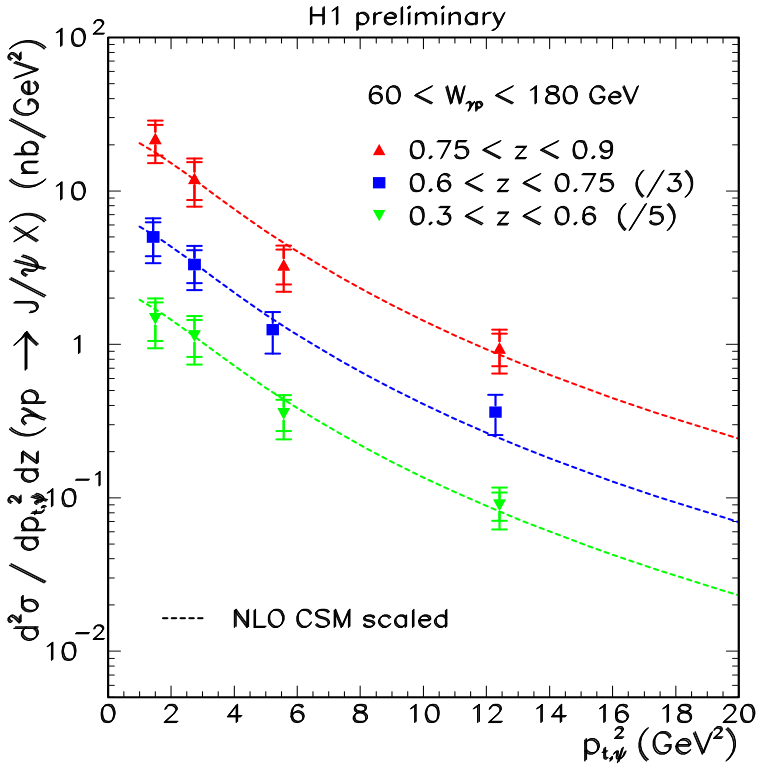
ZEUS 1996-97 Preliminary



• color singlet + octet with CLEO octet matrix elements: looks interesting (no K– factor !)

CLEO octet matrix elements or p_T > 2 GeV ?

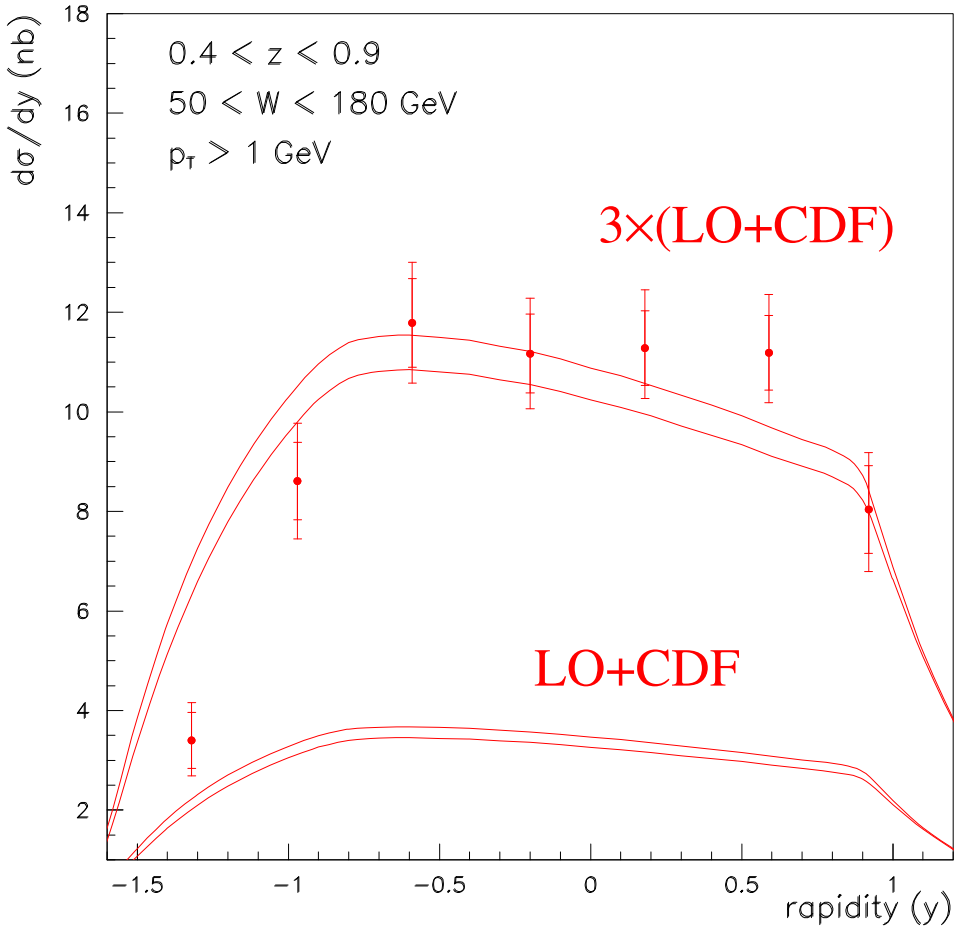




- NLO direct color singlet nicely reproduce shape and normalization

$$\frac{d^2\sigma}{dz dp_T^2} = f(z)\; g(p_T^2)$$

Inelastic ψ

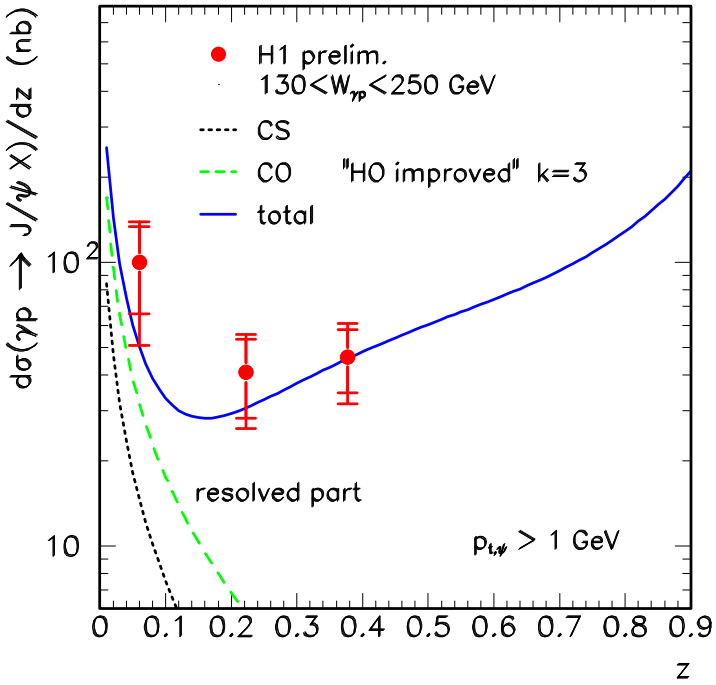


$$y \approx -\tfrac{1}{2} \ln \tan \theta/2$$

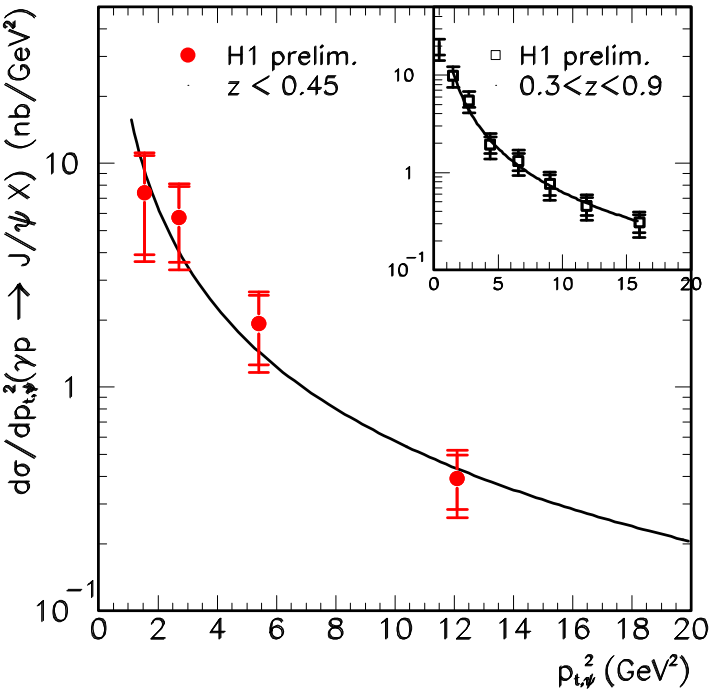
- color singlet + octet with CDF octet matrix elements: undershoots data, some shape discrepancy at negative y (incoming positron direction)
- others predictions ?

Inelastic ψ

- low z region: never explored before HERA

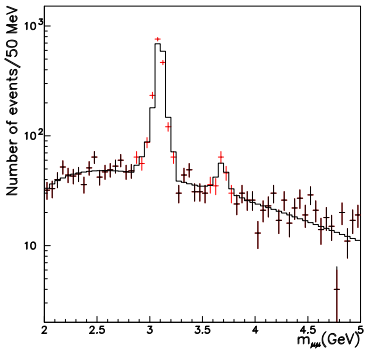


- color singlet + octet with CDF octet matrix elements: undershoots data but shape is fine
- sensitive to the resolved singlet + octet component

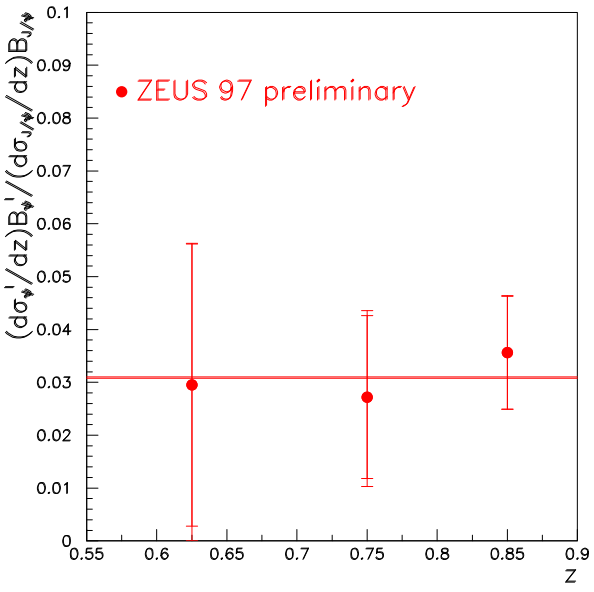


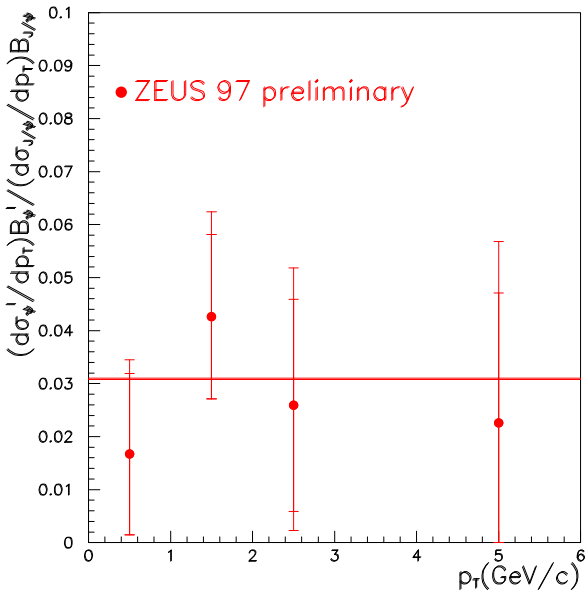
- again the p_T^2 shape does not depend on z

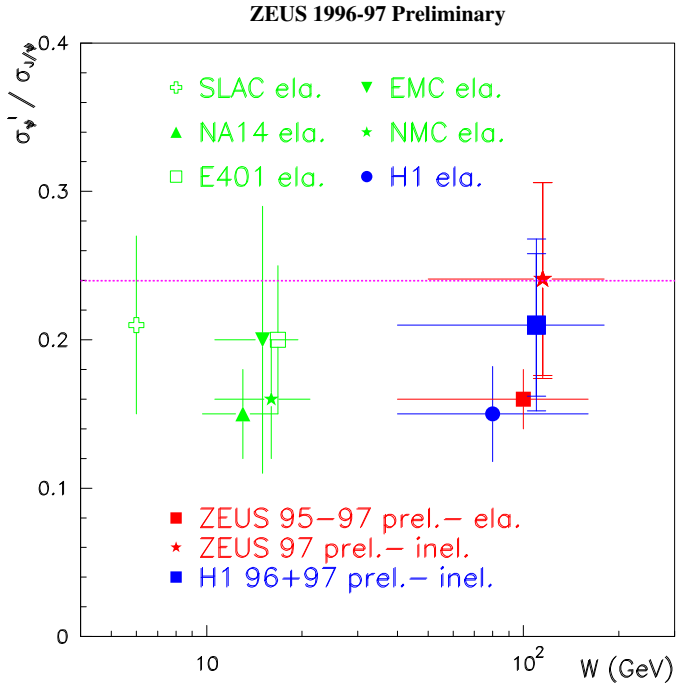
Inelastic charmonium



- first observation at HERA
- $\psi(2S) \rightarrow \psi\,(\rightarrow \mu^+\mu^-)\,X$ contamination



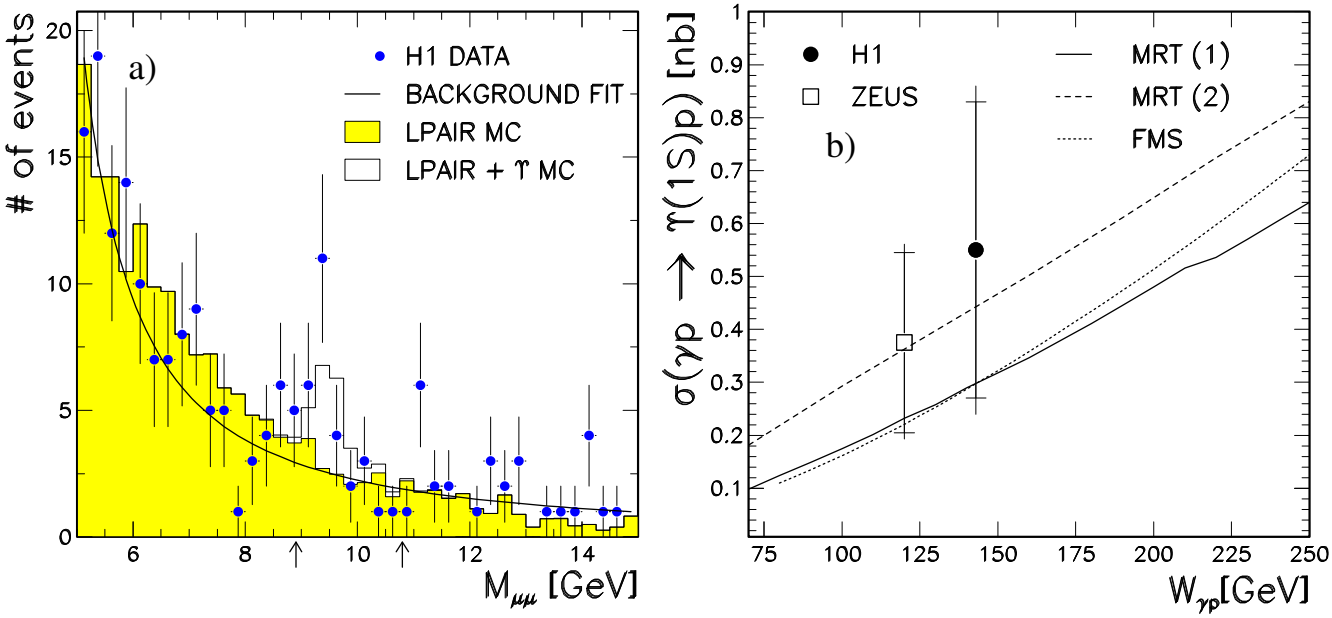




- same production mechanism → flat cross section ratios
- magnitude in agreement with the 24 % naive expectation
- cascade decay gives a 10 % contribution to the ψ cross sections

Elastic Upsilon

- $\Upsilon \rightarrow \mu^+ \mu^-$ $(\Upsilon = \Upsilon(1S) + \Upsilon(2S) + \Upsilon(3S))$
- elastic channel



magnitude of the cross-section can be understood by QCD

Conclusions

- accurate inelastic ψ photoproduction measurements for $z > 0.4$
  - agree with the color singlet direct photon process
  - no need for color octet
- first look at low z ψ : we may need color octet resolved photon
- first look at $\psi(2S)$ / ψ: same production mechanism
- first look at the elastic $\subseteq$ sector: magnitude of the cross section can be understood by QCD
- much more will come:
  - on a short term scale adding 98 $\rightarrow$ 00 data
  - on a longer time scale due to the HERA lumi upgrade (> 2001 150 pb^{-1} / year)