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Elastic J/ψ prod
γp and D

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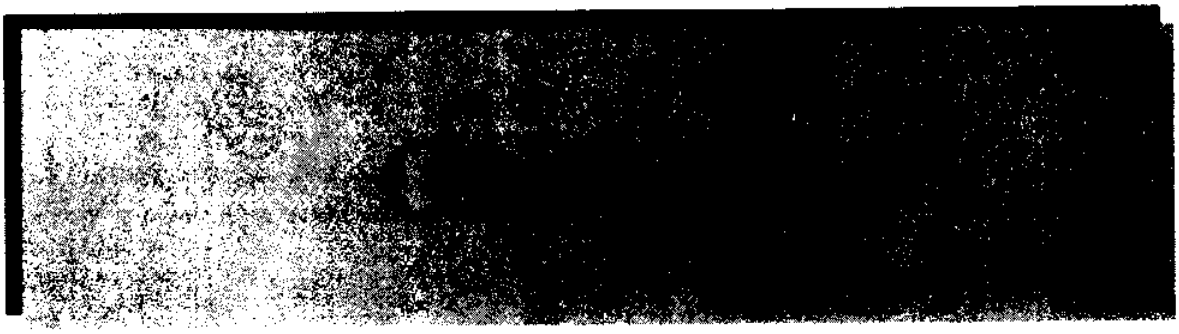
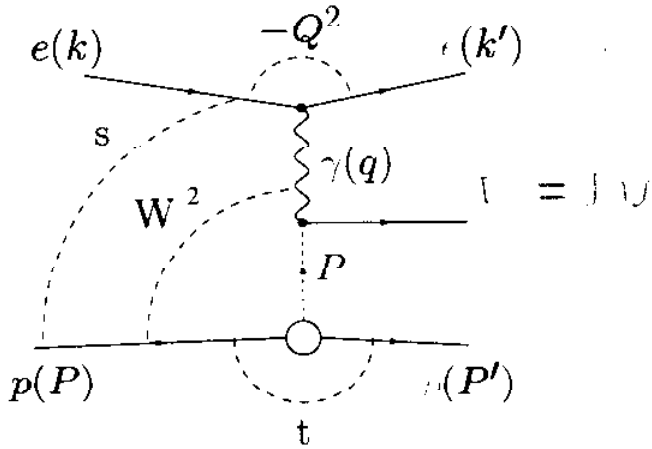
on behalf of the

collaboration



- Kinematics of the process
- Vector Meson production at HERA
- Elastic J/ψ photoproduction
  - Event selection
  - Cross section
  - Differential cross section
  - Helicity
- Elastic J/ψ in DIS
  - Event selection
  - Cross section
  - t slope
- Conclusions

- The positron beam is an intense source of photons



$$s = (P+k)^2 \qquad y = \frac{Q^2}{2P\cdot k - k'}$$

$$Q^2 = -(k-k')^2 \qquad y = \frac{P\cdot k - k'}{P\cdot k}$$

$$W^2 = (P+q)^2 \qquad t = (p-p')^2$$

Access to an unexplored kinematics domain

Large level arm in γp c.m. energy: 40 <W<300 GeV up to **one order of magnitude greater** than in previous fixed target experiment

Vector Meson (ρ^0,ω,ϕ,J/ψ…) production at HERA

Allows to study the transition between soft and hard regime

- **Light Vector Meson production at Q^2~0**

Shows to be a diffractive process

- **Weak dependence of the cross section on energy**
- **Exponential shape in t**
- **SCHC, vector meson retains photon helicity**

VDM – Soft Pomeron

- **When a hard scale is involved one expects pQCD can be applied**

pQCD models

$$\sigma \propto [\alpha_s(\bar{Q}^2)\bar{x}G(\bar{x},\bar{Q}^2)]^2 \qquad \overline{Q^2} \propto Q^2 + M_V^2 - t \qquad \bar{x} \propto \frac{\overline{Q^2}}{W^2}$$

- Cross section very sensitive to gluon density
- High W ⟶ low x

Much stronger energy dependence expected

$M_{J/\Psi}$ large enough to apply pQCD in photoproduction?

HERA well suited to study transition region

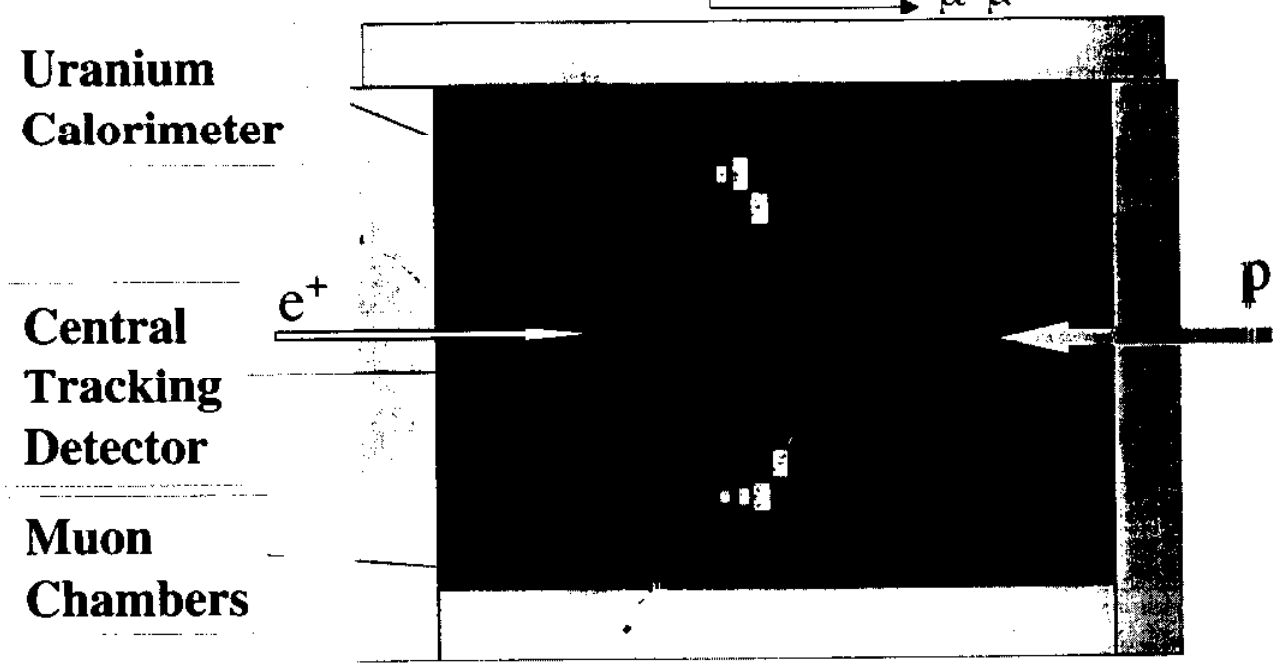
- **possibility to play with all the parameters which define the scale**
- **wide W range to study the cross section energy dependence**

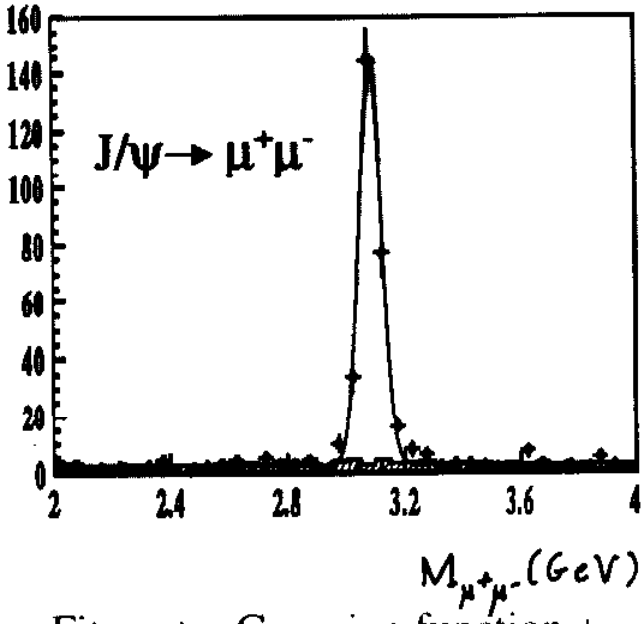
Elastic photoproduction

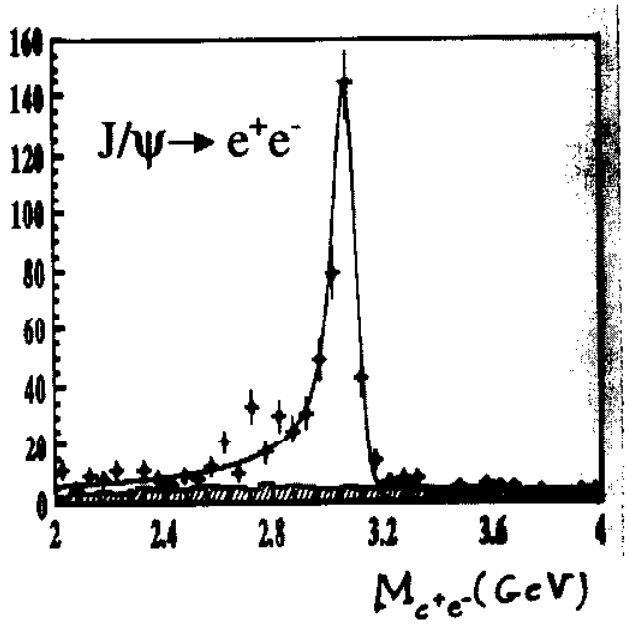
We use Data collected in 1994

- J/ψ detected in both e^+e^- and $\mu^+\mu^-$ channels
- Int. luminosity
  - e^+e^- channel 2.70 pb-1
  - $\mu^+\mu^-$ channel 1.87 pb-1
- Photoproduction requirement
  - ➡ **No scattered positron in the central calorimeter**
    $10^{-10} < Q^2 < 4$ GeV^2 median $Q^2 \sim 5 \cdot 10^{-5}$ GeV^2
- Elastic requirement
  - ➡ **"empty" detector, except for J/ψ decay products**
- $40 < W < 140$ GeV

$\gamma p \longrightarrow J/\psi\, p$, $J/\psi \to \mu^+\mu^-$







- Fit ➡ Gaussian function + flat bg.

$N_{J/\psi} = 266 \pm 17$

$M_{\mu^+\mu} = 3.086 \pm 0.003\ GeV$

- Fit ⇨ Gaussian function + Radiative mass spectrum + polynomial (bg.)

$N_{J/\psi} = 460 \pm 25$

$M_{e^+e^-} = 3.094 \pm 0.003 GeV$

[redacted]

- Pions misidentified as electrons **<1.5%**

- $\psi' \longrightarrow J/\psi\ \pi^0\pi^0$ **(3±1)%**

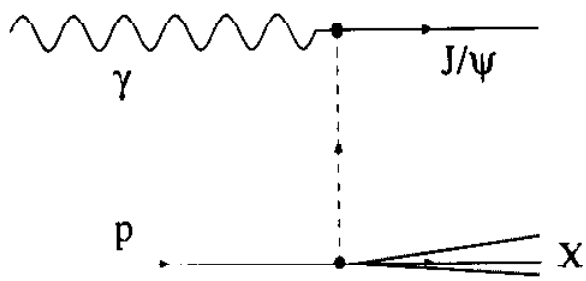
- Bethe - Heitler lepton pair production

Saturates the non resonant background for muons and is the dominant source for electrons

from the fit → electron channel **(8.2 ± 0.2)%**
muon channel **(8.6 ± 0.4)%**

- Proton dissociative J/ψ production

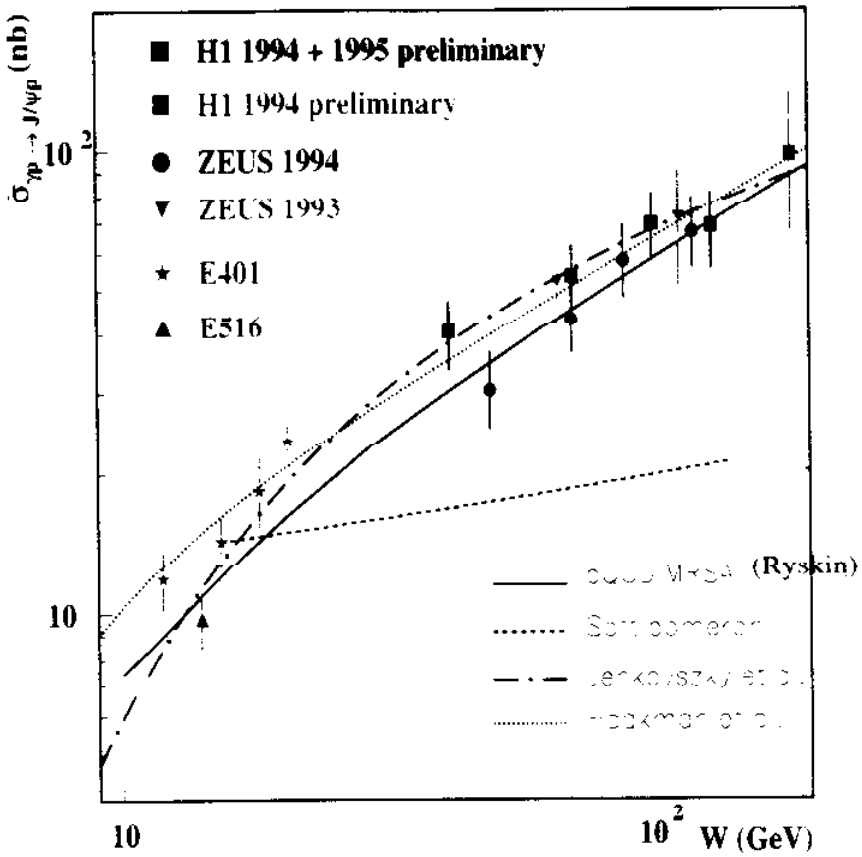
The dissociative system can escape undetected in the forward beam hole



This background was estimated using those events in which part of the system X was detected in forward Calorimeter or in a set of scintillators placed close to the beam pipe around 5 meters from the I.P.

Contamination → $(30^{+9}_{-13})\%$

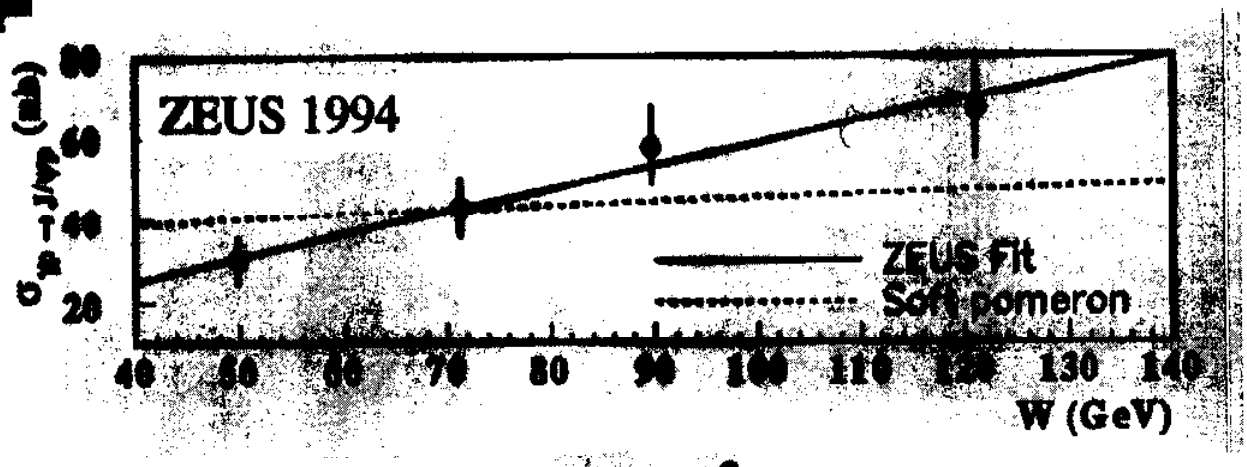
Photo



- **Cross section grows faster than soft pomeron prediction**

Good agreement with data for:

- **Ryskin pQCD inspired model**
- **Pomeron models of Haakman et al. (pomeron intercept depends on the scale) and Jenkovszky et al. (pomeron coupling depends on the scale)**



ZEUS fit $\Longrightarrow$ $\sigma \propto W^{\delta}$

$\delta = 0.92 \pm 0.14 \pm 0.10$

Assuming pQCD

$4 \cdot 10^{-4} < \bar{x} < 6 \cdot 10^{-3}$

$\sigma \sim [\bar{x}G(\bar{x},\bar{Q}^2)]^2$

$\bar{x}G(\bar{x},Q^2_0) \sim \bar{x}^{-\lambda}$

$\Rightarrow \sigma \sim W^{4\lambda}$

$\lambda = 0.23 \pm 0.04(stat.) \pm 0.03(syst.)$

Consistent with ZEUS measurement in F2 scaling violation

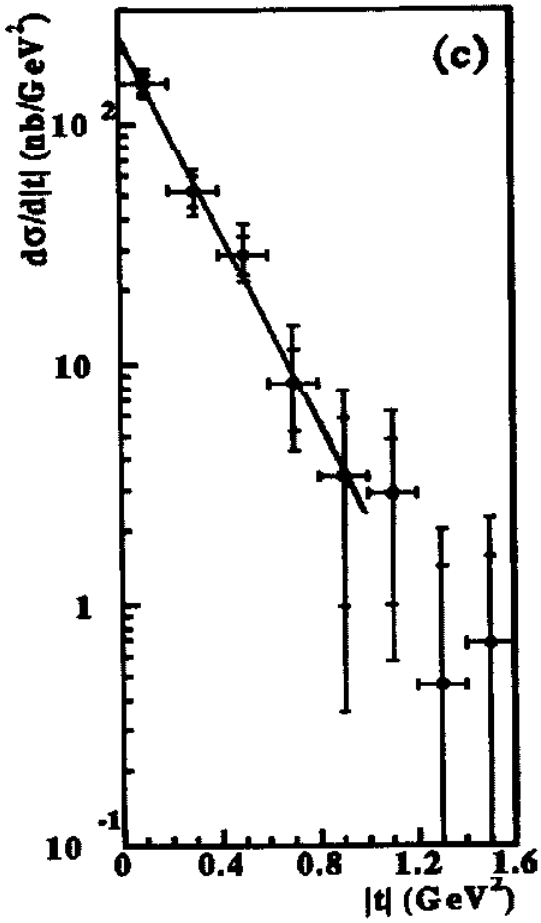
Soft pomeron $\Longrightarrow$

$\varepsilon = \alpha_{pom}(0) - 1 = 0.08$ (Donnachie Landshoff fit)

$\sigma \propto \dfrac{W^{4\varepsilon}}{b(W^2)} \approx W^{0.22}$

Differential cross section

- Exponential fall characteristic of diffractive process



$$\frac{d\sigma}{dt} \sim e^{-b|t|}$$

$|t| < 1 GeV^2$

[redacted]

$\rho^0 \longrightarrow b = 9.8 \pm 0.8 \pm 1.1 GeV^{-2}$

$\omega \longrightarrow b = 10.0 \pm 1.2 \pm 1.3 GeV^{-2}$

$\phi \longrightarrow b = 7.3 \pm 1.0 \pm 0.8 GeV^{-2}$

Geometrical model of vector meson production

➡ J/ψ radius is smaller than light vector meson at $Q^2 \sim 0$

Preliminary ZEUS results on ρ^0 in DIS ($Q^2 \sim 12$ GeV^2) give $b \sim 6$ GeV^{-2}

➡ The slope decreases with increasing scale

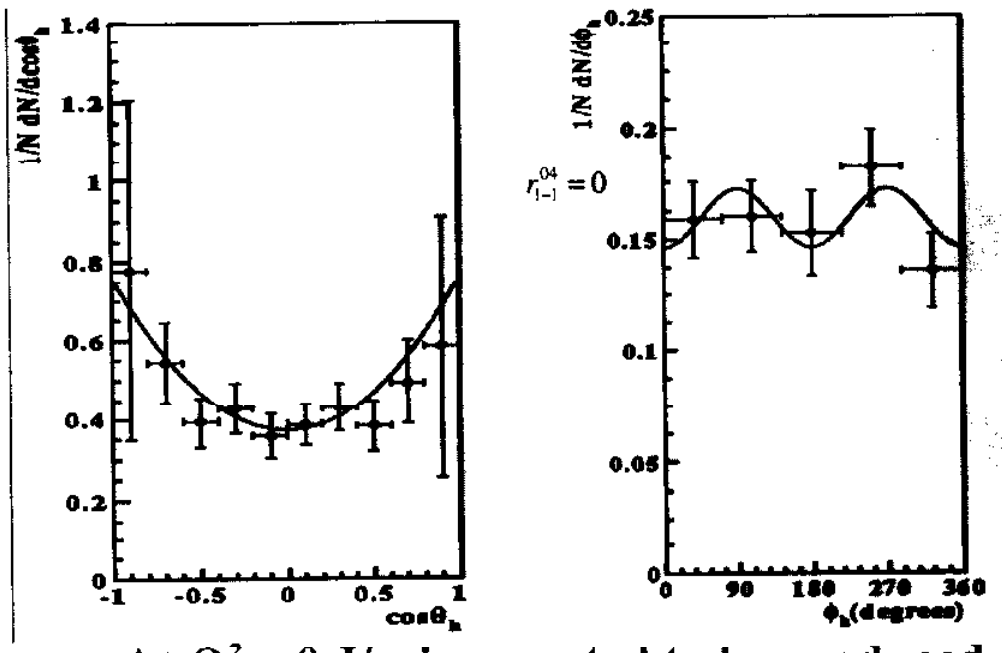
J/ψ helicity

We measure θ_h, ϕ_h , the polar and azimuthal angle of the positive lepton in the helicity frame (defined as the J/ψ rest frame with quantization axis along the J/ψ direction in γp frame)

$$\frac{1}{N}\frac{dN}{d\cos\vartheta_h} = \frac{3}{8}[1 + r_{00}^{04} + (1 - 3r_{00}^{04})\cos^2$$

$$\frac{1}{N}\frac{dN}{d\phi_h} = \frac{1}{2\pi}[1 + r_{1-1}^{04}\cos 2\phi_h]$$

$r_{00}^{04}, r_{1-1}^{04}$ are elements of the J/ψ spin-density matrix



- **At $Q^2 \sim 0$ J/ψ is expected to be produced predominantly by transverse photons**

$r_{00}^{04} \approx 0$, $r_{1-1}^{04} = 0$ ➡ Zero ➡ $r_{00}^{04} = -0.01 \pm$, $r_{1-1}^{04} = -0.08 \pm$

- **<u>J/ψ retains the photon helicity</u>**

Elastic J/ψ

We use Data collected in 1995

- Rear calorimeter modules moved closer to the beam pipe
  → higher acceptance at low Q^2

Statistics increased by a factor ~10 respect to 1994

- Int. luminosity ~ 6 pb^{-1}

- Elastic requirement
  ➡ **"empty" detector except for J/ψ decay products and scattered positrons**

- DIS requirement
  ➡ **Scattered e^+ detected in Calorimeter with E> 8 GeV**

  $2 < Q^2 < 40\ GeV^2$

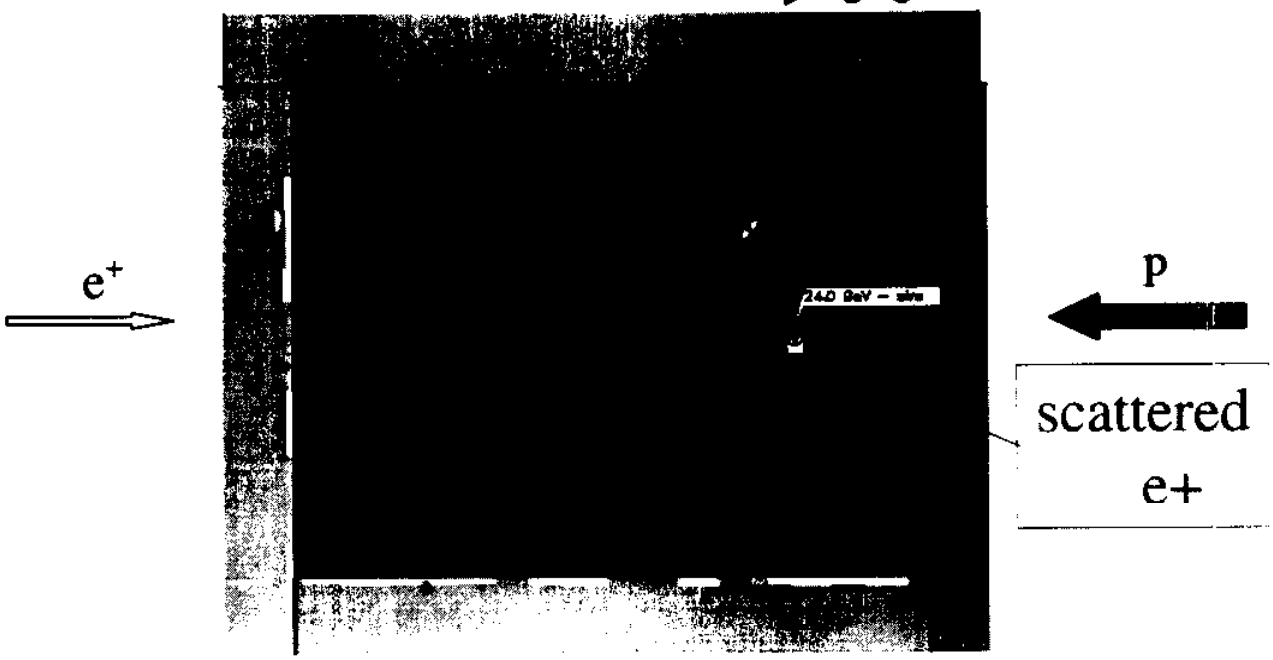
- $50 < W < 150$ GeV

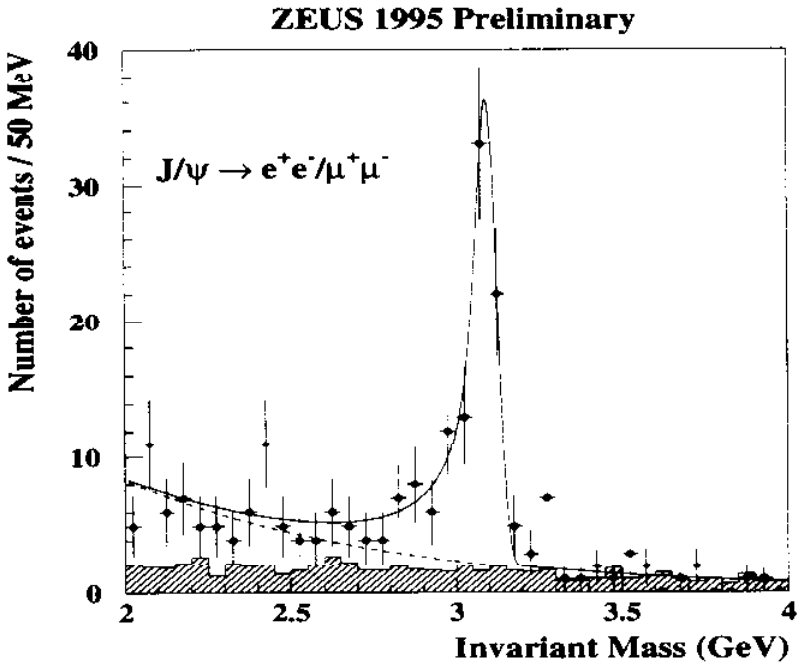
Elastic J/ψ production in γp and DIS

L.Bellagamba

$$ep \longrightarrow eJ/\psi\, p$$

$$J/\psi \longrightarrow e^+e^-$$





- Fit ➡ Gaussian resolution + radiative mass spectrum+ polynomial (bg)

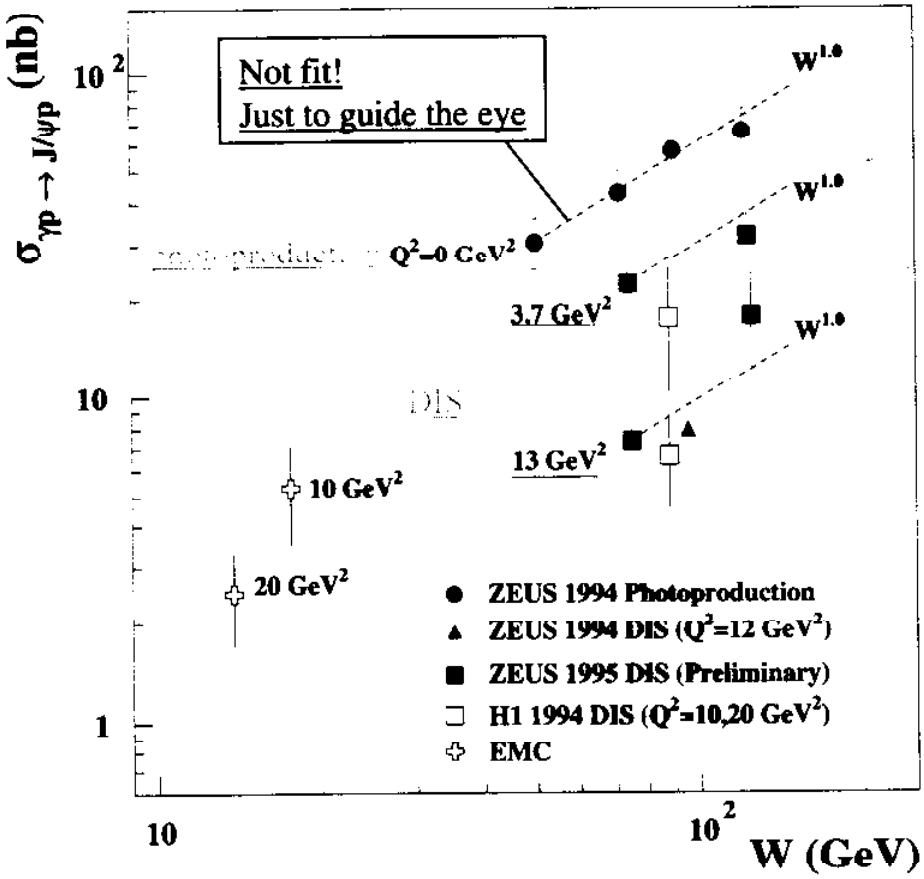
$$M_{l^+l^-} = 3.114 \pm 0.006 GeV$$

$$N_{J/\psi} = 98 \pm 12$$

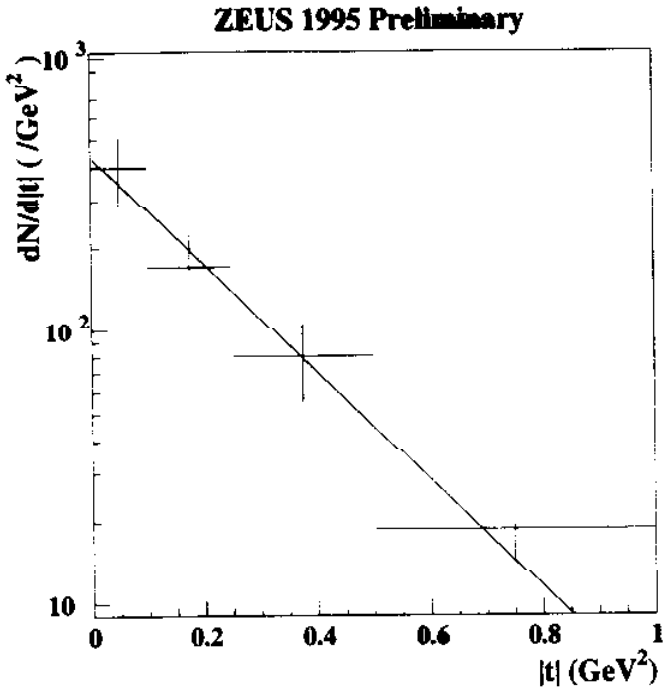
[redacted]

• Proton dissociation subtracted [redacted]

$$\sigma_{tot}=\sigma_T+\varepsilon\cdot\sigma_L$$



• **Cross section behaviour with energy similar to photoproduction**



$2<Q^2<40\,GeV^2$ $55<W<125\,GeV$

$$\frac{dN}{d|t|} \propto e^{-b|t|}$$

$$|t|<1\,GeV^2$$

→ Compatible with photoproduction result

Conclusions

- Elastic J/ψ production at HERA allows to probe an unexplored kinematics region and to test the pQCD applicability.
  - Typical features of diffractive processes, like exponential t behaviour and SCHC, are observed.
  - The strong rise of the cross section with center of mass energy reflects the increasing gluon density at low x and indicates that pQCD is applicable.
- Preliminary DIS results.
  - Statistics increased ~ 10 respect to 1994.
  - strong W dependence of the cross section (even if errors are still large) as observed in photoproduction.