Diffractive Photoproduction of $\psi(2S)$ Mesons at HERA

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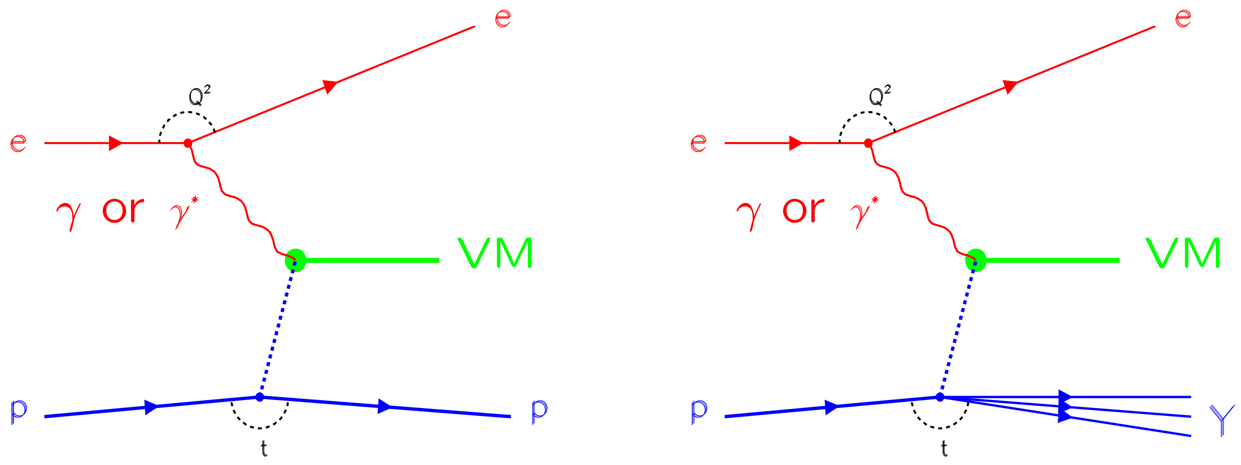
Diffractive Vector Meson Production at HERA

proton elastic proton dissociative



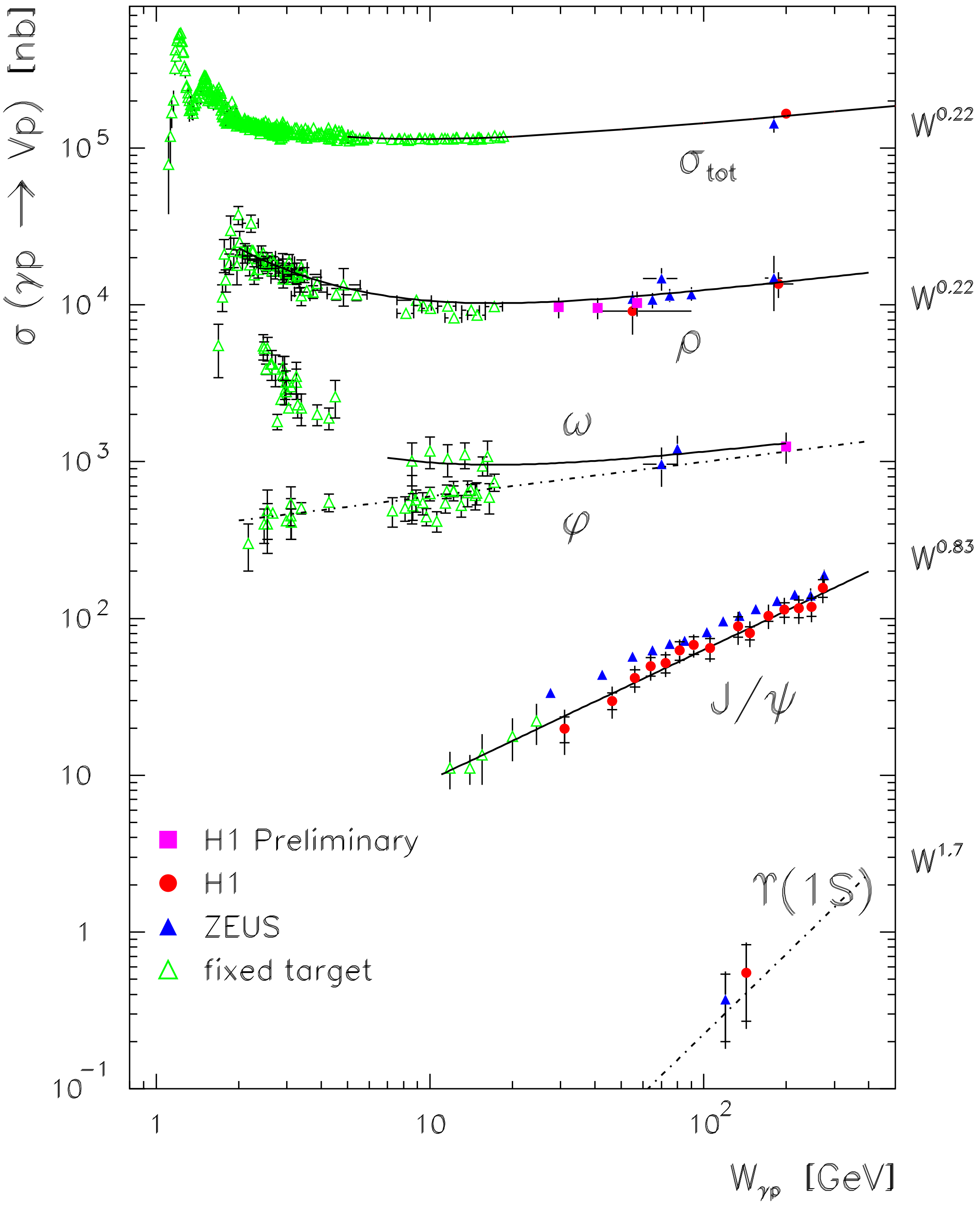
Q^2	γ^* Virtuality	$\sim 0 < Q^2 < 100\,\text{GeV}^2$
$W_{\gamma p}$	CM Energy of $\gamma^* p$ system	$20 < W_{\gamma p} < 290\,\text{GeV}$
t	(4-mom. transfer at p vertex)^2	$\sim 0 < \lvert t \rvert < 20\,\text{GeV}^2$
VM	Light Vector Mesons	$\rho^0,\ \omega,\ \phi$
	Heavy Vector Mesons	$J/\psi,\ \psi(2S),\ \Upsilon$

$\Rightarrow$ Simultaneous Probe of Different Kinematical Quantities.

Bound $c\bar{c}$ States $\Rightarrow$ Probe Meson Wavefunctions

Elastic Photoproduction $\gamma p \to Vp$

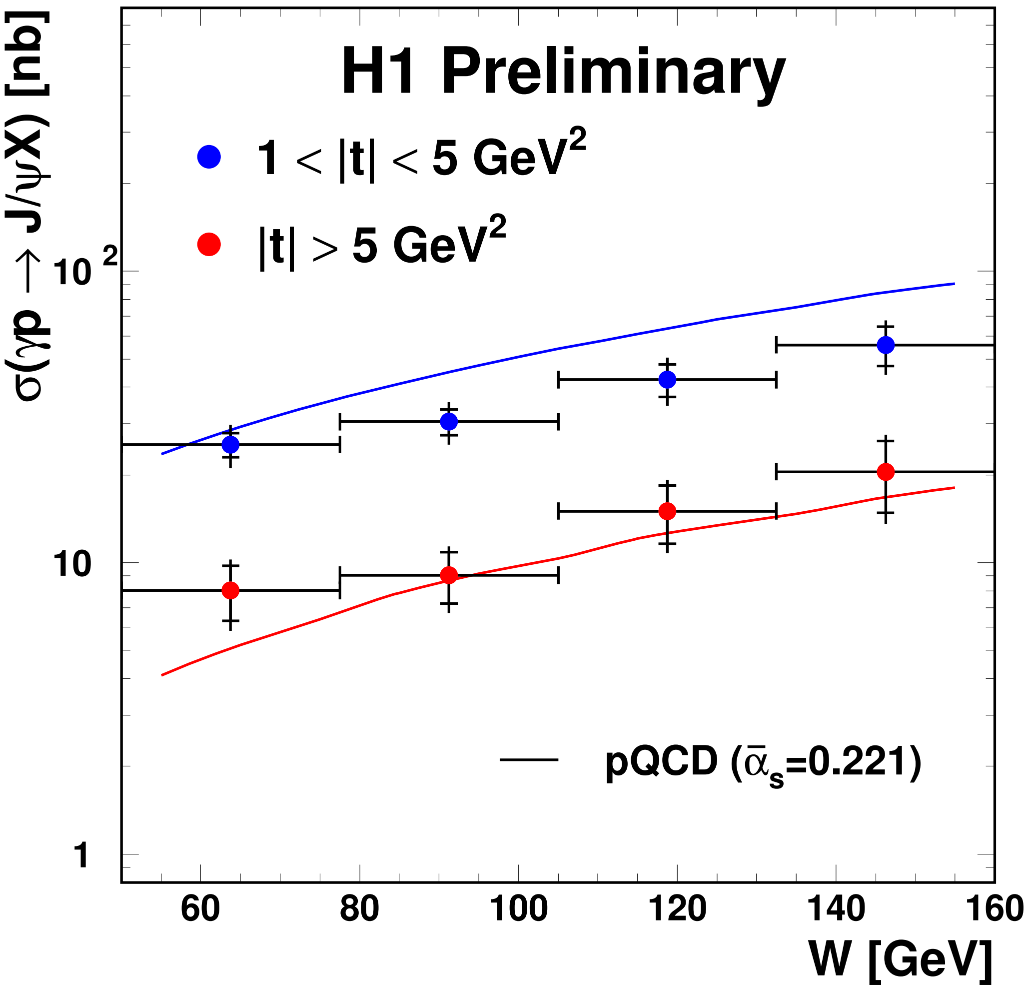
$Q^2 \approx 0$, $|t| \approx 0$, M^2_{VM} hard-scale



$\Rightarrow$ Steeper rise in the J/ψ cross section

Proton Dissociative J/ψ Photoproduction at Large $|t|$

- Similar rise ($W_{\gamma p}^{\delta}$; $\delta \sim 1$) measured at large $|t|$



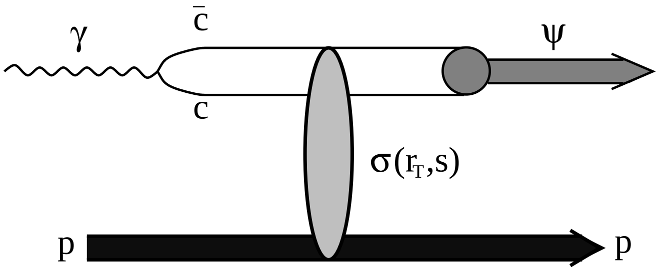
- $50 < W_{\gamma p} < 160$ GeV
- $Q^2 < 1.0$ GeV^2
- $1.0 < |t| < 21.0$ GeV^2

[1] Forshaw and Ryskin, Z. Phys.C68 (1995) 137-148

[2] Bartels, Forshaw, Lotter, Wüsthoff, Phys.Lett.B375 (1996) 301-309

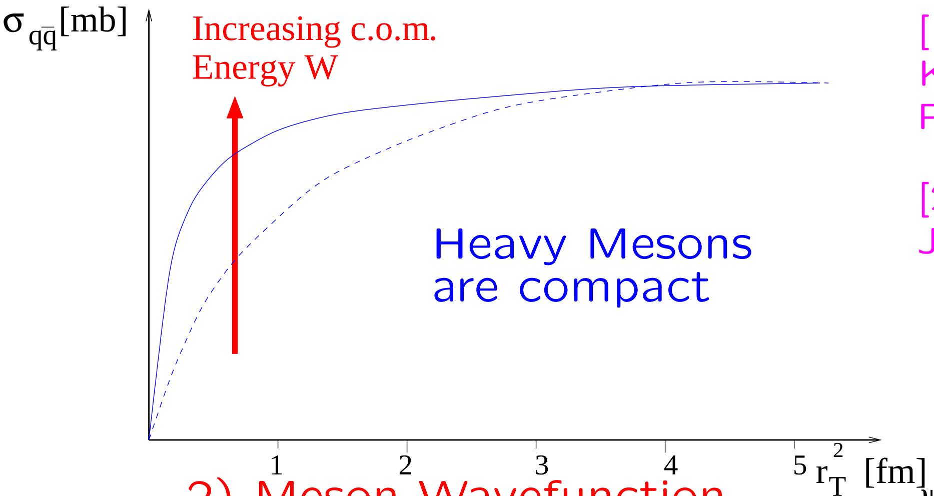
$\Rightarrow$ BFKL Model ($\bar{\alpha}_s \sim 0.2$) describes behaviour

Diffractive $\psi(2S)$ Production in the Colour Dipole Model



1) Total Dipole Cross Section

- Depends on $q\bar{q}$ separation and $s = W_{\gamma p}^2$



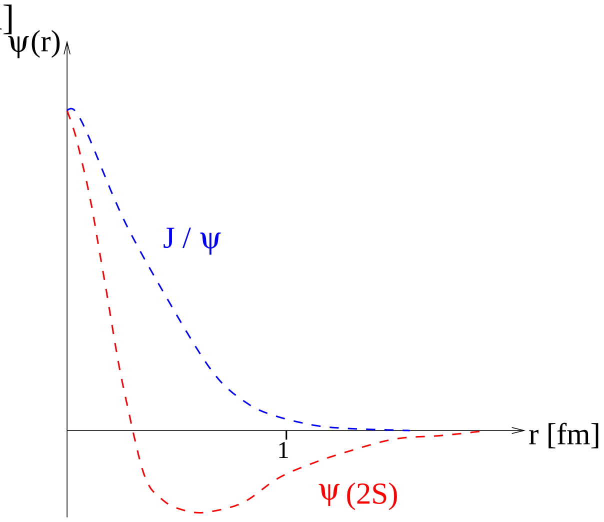
[1] Hüfner, Y.P.Ivanov, Kopeliovich et al., Phys.Rev. D62(2000)

[2] Nemchik et al., J.Exp.Theor. 86(1998)

2) Meson Wavefunction

- First radial excitation $\psi(2S)$ differs from J/ψ:

a) ⟨radius⟩ larger than J/ψ
b) Wavefunction has a node



$\Rightarrow$ $\psi(2S)$ production suppressed

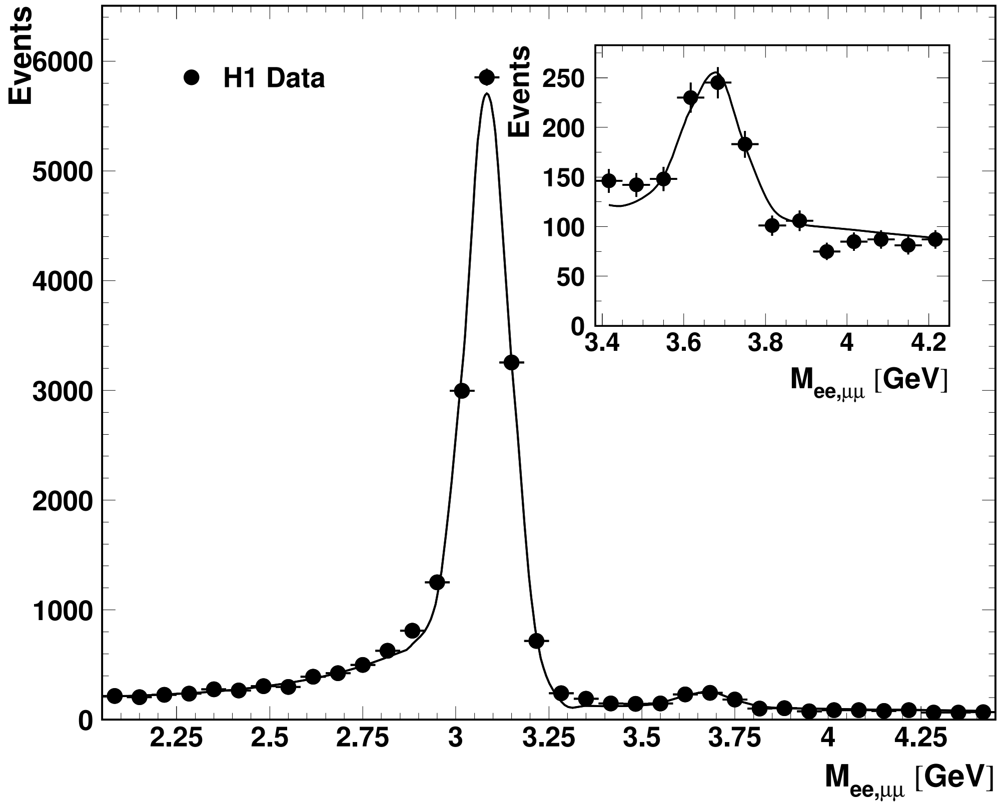
$\Rightarrow$ slightly steeper rise in $W_{\gamma p}$

$\Rightarrow$ $|t|$ dependence : $\exp(-b|t|)$: $b_{\psi(2S)} \lesssim b_{J/\psi}$

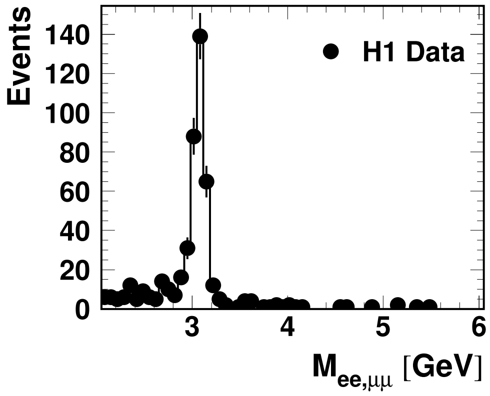
Diffractive $\psi(2S)$ Photoproduction
HERA-I Event Samples

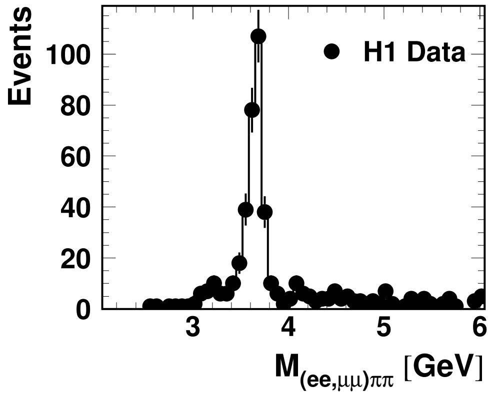
- 2 Prong Sample: $\psi(2S) \to l^+l^-$

$\psi(2S)$: Larger relative bkgd (mainly $\gamma\gamma \to l^+l^-$)



- 4 Prong Sample : $\psi(2S) \to (J/\psi \to l^+l^-)\pi^+\pi^-$





Diffractive Photoproduction of $\psi(2S)$

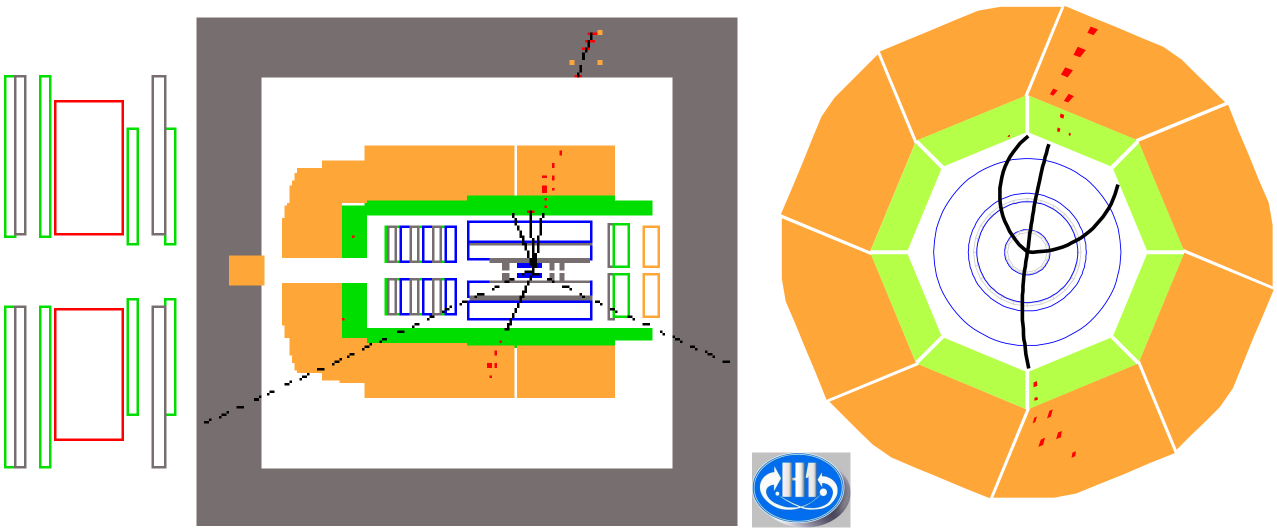
H1 Result:

- Integrated Luminosity $77\,\mathrm{pb}^{-1}$
- $Q^2 < 1\,\mathrm{GeV}^2$
- $40 < W_{\gamma p} < 150\,\mathrm{GeV}$

($z > 0.95$ for proton dissociative events)

2 Prong Events:
$\psi(2S) \to l^+l^-$
4 Prong Events (Cascade Decays):
$\psi(2S) \to (J/\psi \to l^+l^-)\pi^+\pi^-$

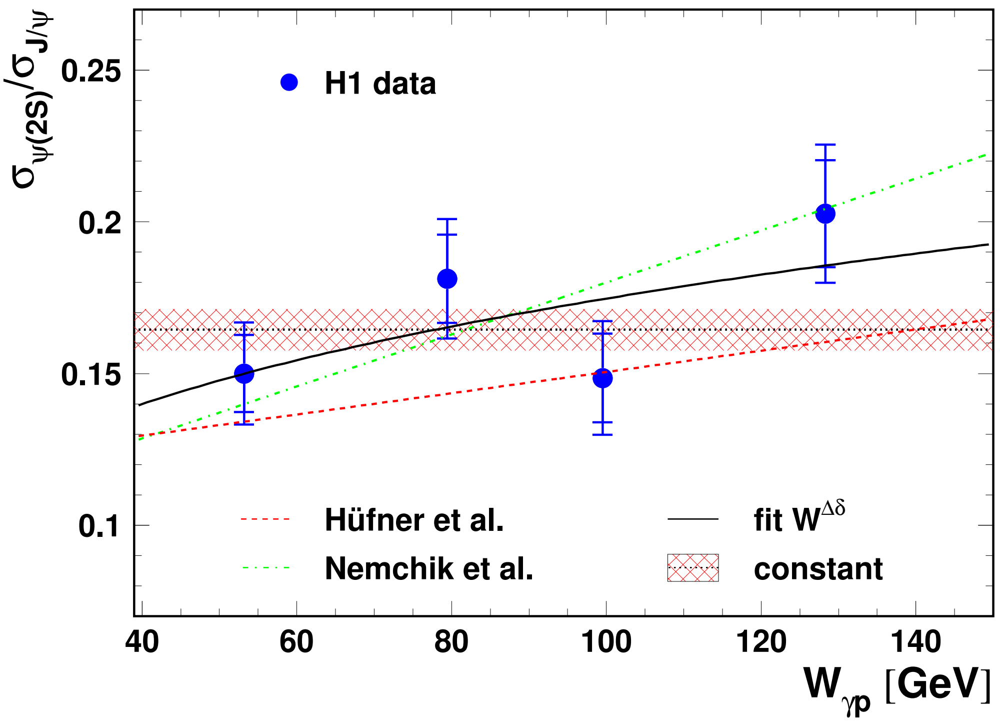
4 Prong Events with the H1 Detector:



Events Distinguished using Forward Detectors
- Forward Tagged $\sim$ Proton Dissociative
- Forward Untagged $\sim$ Proton Elastic

Measured Cross Section Ratio

- Total diffractive ratio (tagged + untagged)



- Average Ratio: $\langle R \rangle$

$= 0.166 \pm 0.007(stat.) \pm 0.008(sys.) \pm 0.007(BR)$

$\Rightarrow$ Agreement with previous measurements (H1/ZEUS)

- Fit $\sim W_{\gamma p}^{\Delta\delta}$ where $\Delta\delta$ rise relative to the J/ψ;

$$\Delta\delta = 0.24 \pm 0.17$$

$\Rightarrow$ $\sigma_{\psi(2S)}$ similar / possibly steeper than $\sigma_{J/\psi}$

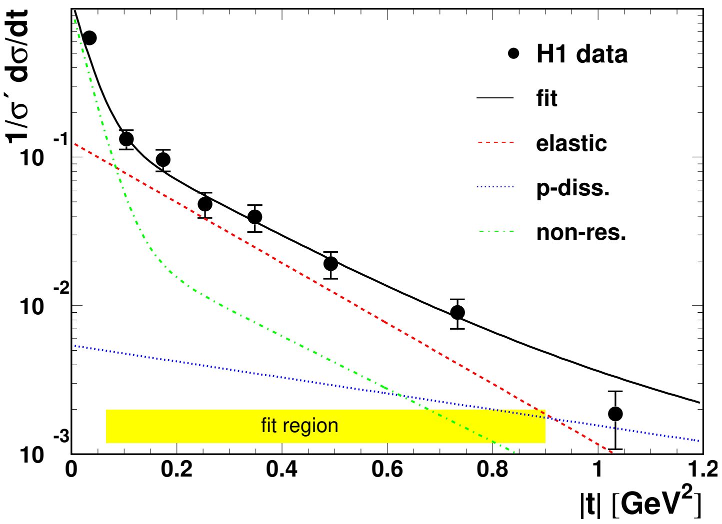
$\Rightarrow$ Colour Dipole Models reproduce ratio.

Measurement of the $|t|$ Dependence

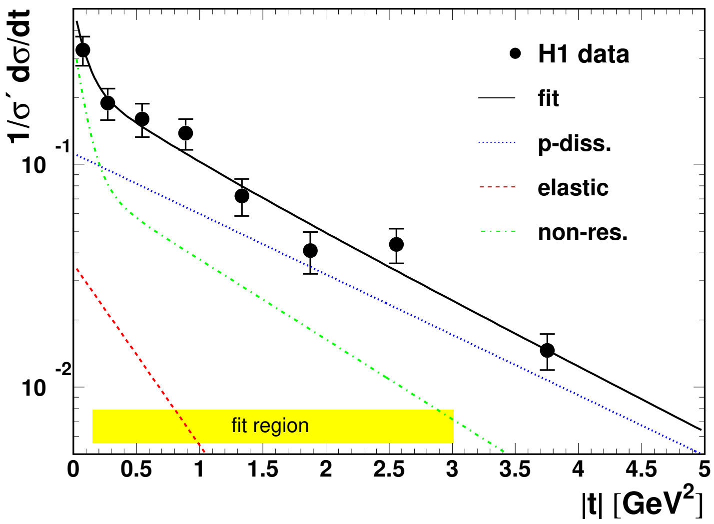
- Events counted in mass window $\pm 150\,\mathrm{GeV}$ around nominal $\psi(2S)$ mass

- 2 Prong Events:

Forward Untagged



Forward Tagged



- Relative contribution of Non-Resonant BKGD:

$\Rightarrow$ Measured as a function of $|t|$ (sidebands).
$\Rightarrow$ Relative contribution + $|t|$ dependence fixed.

- Elastic and proton-dissociative b-slopes

$\Rightarrow$ Extract two slopes from two samples
$\Rightarrow$ Iterative Procedure is used: Fit $\sim A\exp(-b|t|)$

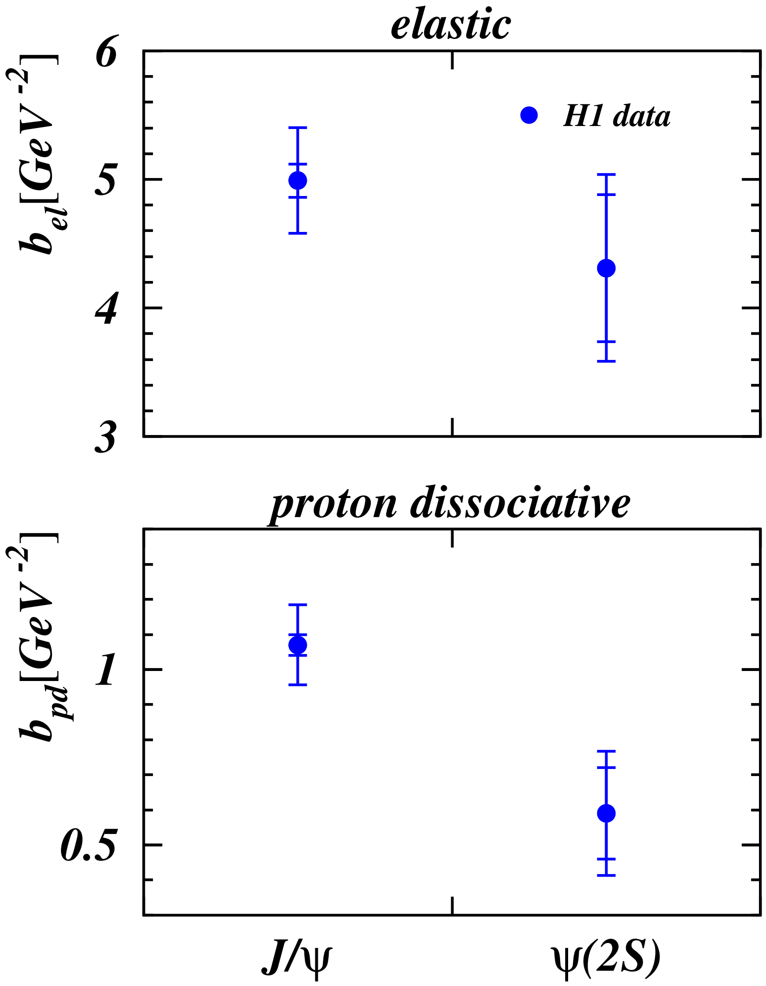
- 4 Prong sample $\Rightarrow$ Equivalent Procedure

Results: $|t|$ Dependence

- Measured elastic and proton-diss. b-slopes;

$\gamma p \rightarrow \psi(2S)p$ $\quad b_{el}^{\psi(2S)} = (4.31 \pm 0.57 \pm 0.45)\ \mathrm{GeV}^{-2}$

$\gamma p \rightarrow \psi(2S)Y$ $\quad b_{pd}^{\psi(2S)} = (0.59 \pm 0.13 \pm 0.12)\ \mathrm{GeV}^{-2}$



$b_{el}^{J/\psi} = (4.99 \pm 0.13 \pm 0.39)\ \mathrm{GeV}^{-2}$

$b_{pd}^{J/\psi} = (1.07 \pm 0.03 \pm 0.11)\ \mathrm{GeV}^{-2}$

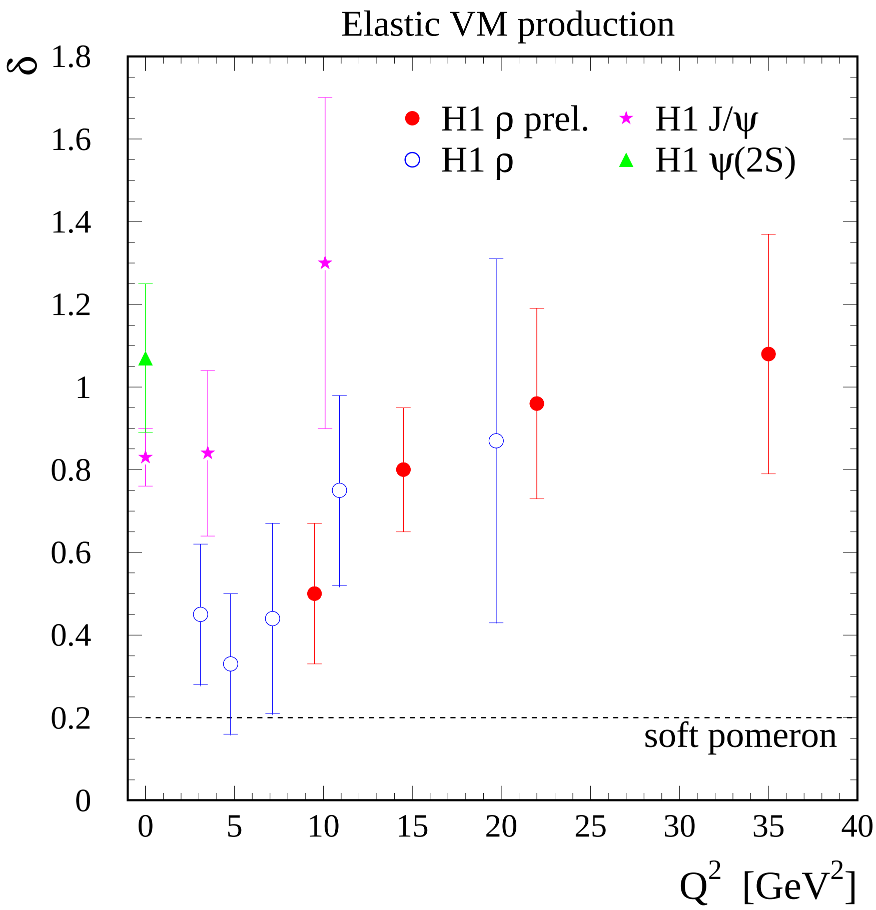
- Difference $\psi(2S)$ and J/ψ;

$\Rightarrow$ ψ(2S) Node Effect.

- Proton elastic/diss. $\Rightarrow$ Proton Form Factor

Elastic Electroproduction : $\gamma^* p \to V p$

- The $W_{\gamma p}$ dependence of lighter vector mesons evolve as a function of Q^2

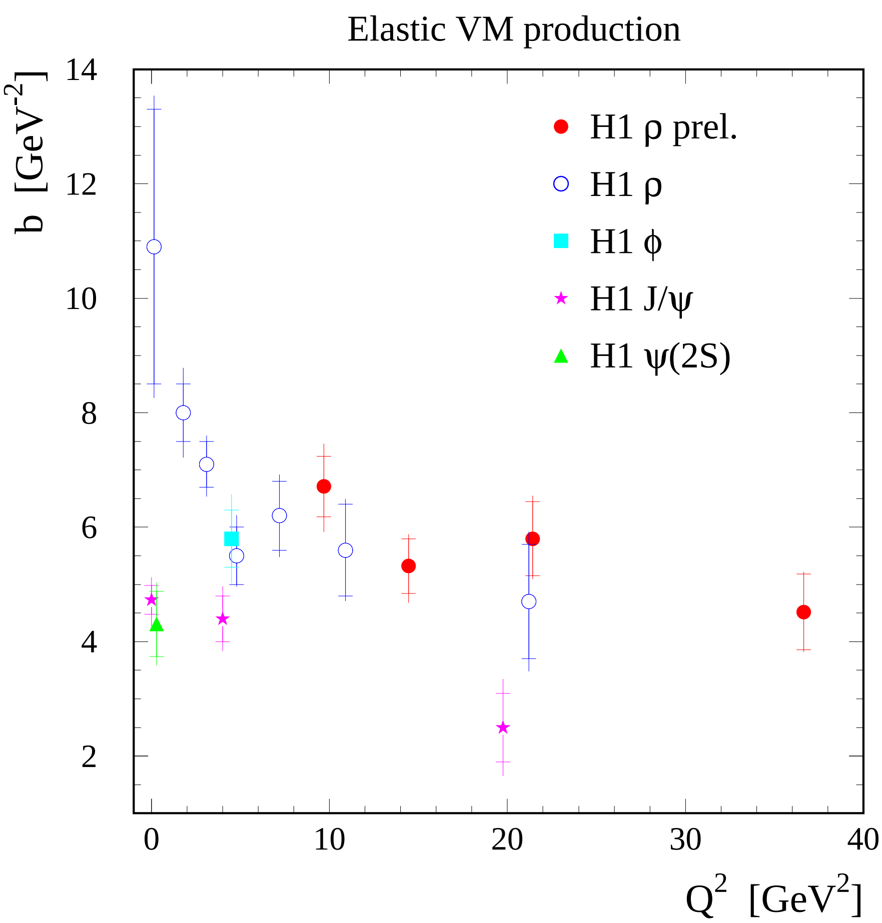


- For large enough Q^2:

$\Rightarrow$ behave as heavy vector mesons at $Q^2 \approx 0$

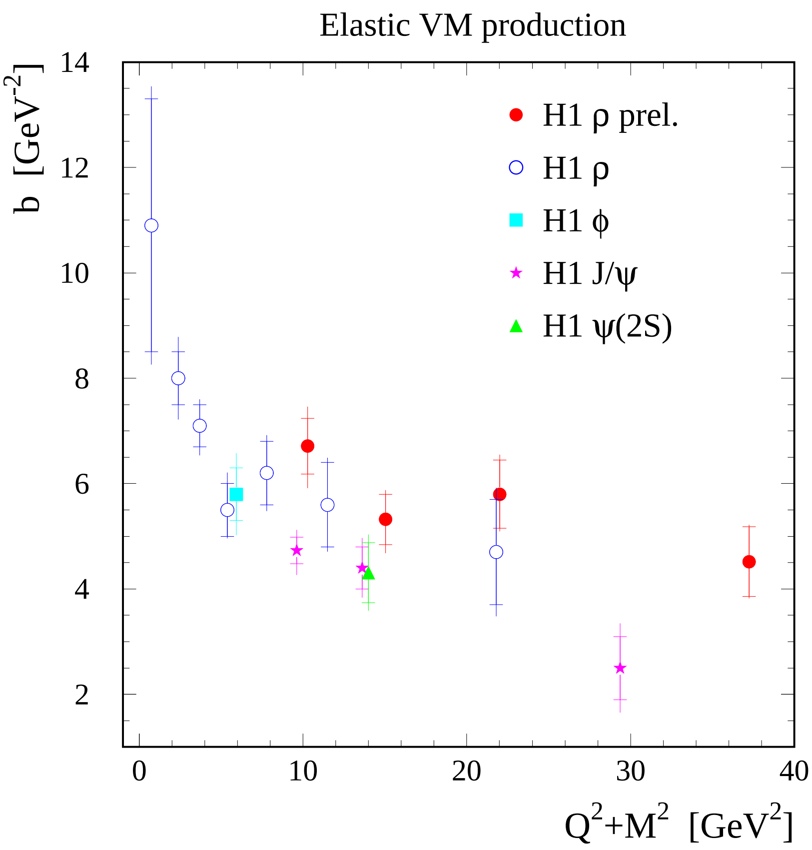
Elastic Electroproduction : $\gamma^* p \rightarrow V p$

- Similar effect as a function of $|t|$:



Elastic Electroproduction : $\gamma^* p \to Vp$

- Plot as a function of $Q^2 + M_V^2$:



Conclusions

- Diffractive $\psi(2S)$ Photoproduction

  $\Rightarrow$ Measured in $W_{\gamma p}$ and $|t|$

- Total Diffractive Ratio

  $\Rightarrow$ $\sigma_{\psi(2S)}/\sigma_{J/\psi} \sim 0.17$

- Rise $\sigma_{\psi(2S)}(W_{\gamma p})$ as a Function of $W_{\gamma p}$;

  $\Rightarrow$ Similar/Possibly Steeper than J/ψ

- Cross Sectional $|t|$-Dependencies;

  $\Rightarrow$ $b_{el}^{\psi(2S)} \lesssim b_{el}^{J/\psi}$

  $\Rightarrow$ $b_{pd}^{\psi(2S)}$ smaller than $b_{pd}^{J/\psi}$

- Described by Colour Dipole Predictions which include $\psi(2S)$ Node Effect.
  (Nemchik et al./ Hüfner et al.)