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On behalf of the
H1 Collaboration

ρ meson electroproduction at high Q^2 and high $|t|$

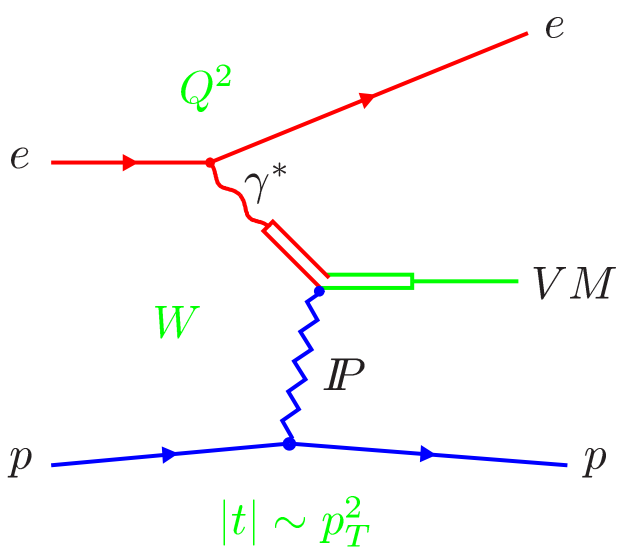
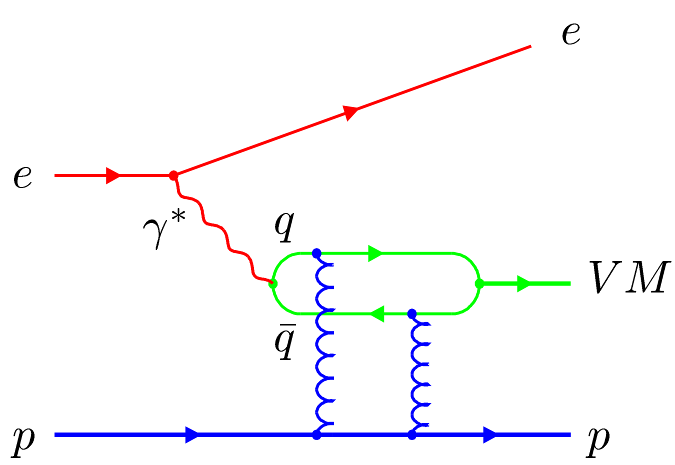
- High Q^2 :
  - Q^2 dependence
  - W dependence $\longrightarrow$ $\langle \alpha_{I\!P}(t) \rangle$
  - t dependence
- High $|t|$ and high Q^2 :

  Spin Density Matrix Elements in comparaison with pQCD

DIS 2002 - Cracow
April 30 - May 4, 2002

INTRODUCTION

$$e + p \rightarrow e + VM \; (= \rho, \omega, \phi, J/\psi, \psi') + p$$

Regge Theory	pQCD Models
	
Soft $I\!P$omeron exchange	Exchange of $\geq$ 2 gluons
$\sigma \propto (\frac{W}{W_0})^{4(\alpha_{I\!P}(t)-1)}$	$\sigma \propto (xG(x,Q^2))^2$
$\alpha_{I\!P}(t) = 1.08 - 0.25\|t\|$	Steep rise of $xG(x,Q^2)$
Works for light VM at low Q^2 (and low t)	Requires hard scale: Q^2, m_q (or maybe t)

ρ at high Q^2 provides a laboratory to investigate transition between soft and hard regimes

ρ PRODUCTION: DATA SELECTION

$$e + p \rightarrow e + \rho + p \ (or \ Y)$$

$$\rho \rightarrow \pi^+ + \pi^-$$

- DIS domain: 1 electromagnetic cluster $\rightarrow$ e
- 2 charged tracks $\rightarrow \pi^+ \ \pi^-$
- no additional cluster
- NOTAG : empty forward detectors ($\simeq$ Elastic)
- TAG : activity in forward detectors ($\simeq$ Proton dissociation)

High Q^2 :

2000 data $\rightarrow$ 42 pb^{-1}

NOTAG ONLY $\rightarrow$ Elastic

$$Q^2 > 8.0 \text{ GeV}^2$$

$$40 < W < 180 \text{ GeV}$$

$$|t| < 0.5 \text{ GeV}^2$$

High $|t|$:

1997 data $\rightarrow$ 6 pb^{-1}

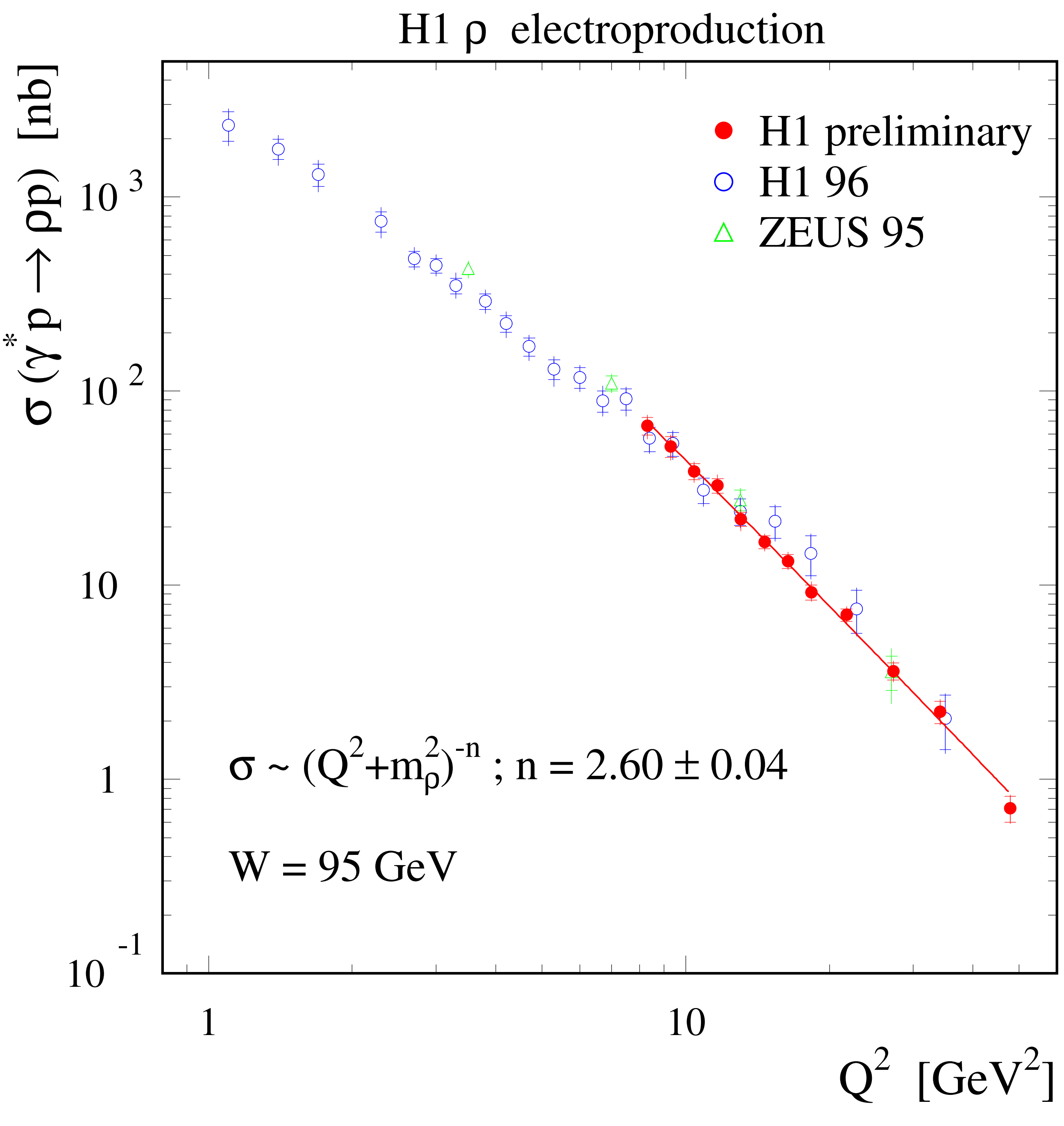
NOTAG + TAG

$$Q^2 > 2.5 \text{ GeV}^2$$

$$40 < W < 120 \text{ GeV}$$

$$|t| < 3.0 \text{ GeV}^2$$

HIGH Q^2: TOTAL CROSS SECTION

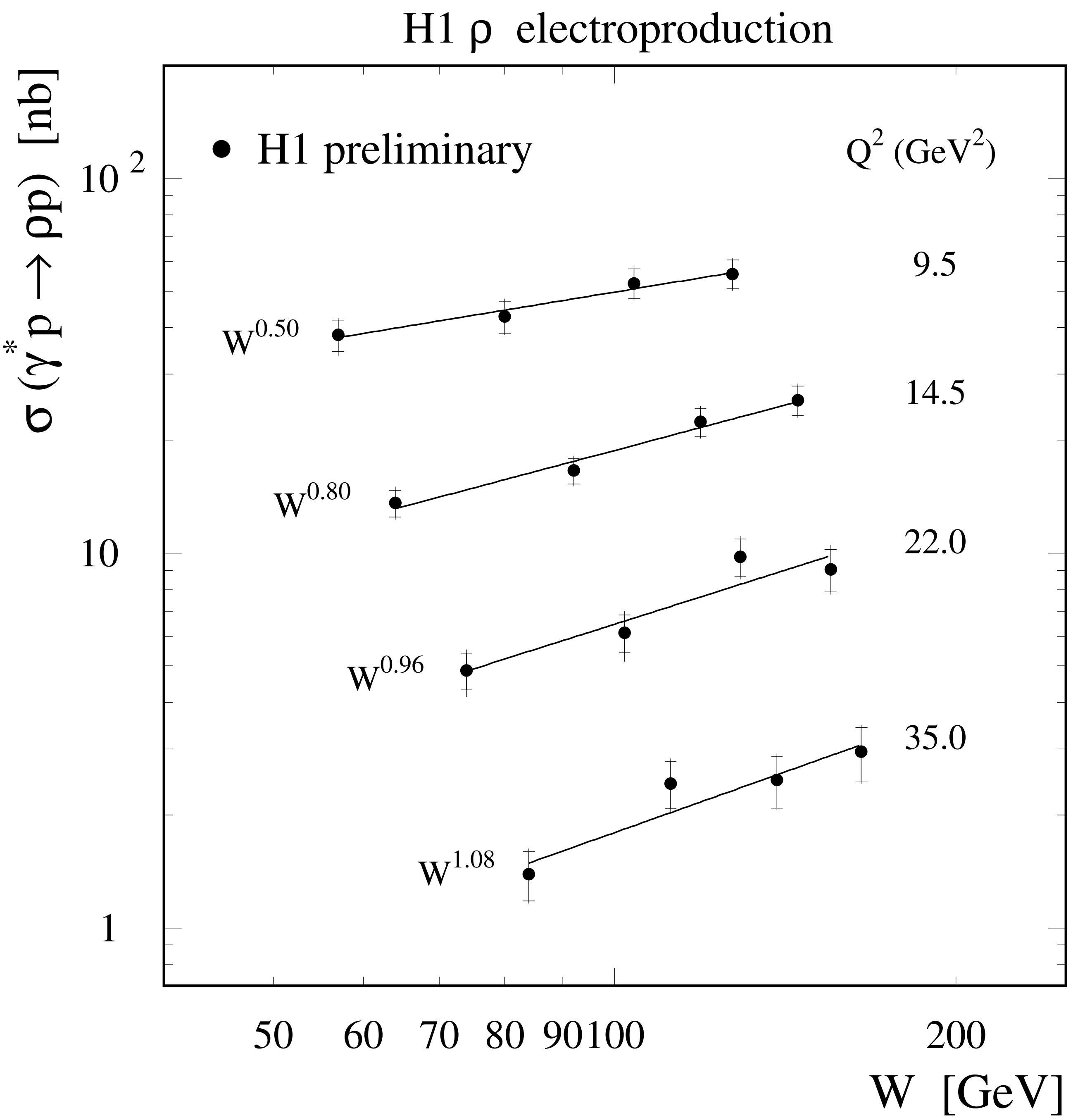


For 96 data $(Q^2 > 1\ GeV^2)$: $n = 2.24 \pm 0.09$

High precision reached at high Q^2

HIGH Q^2: W DEPENDENCE

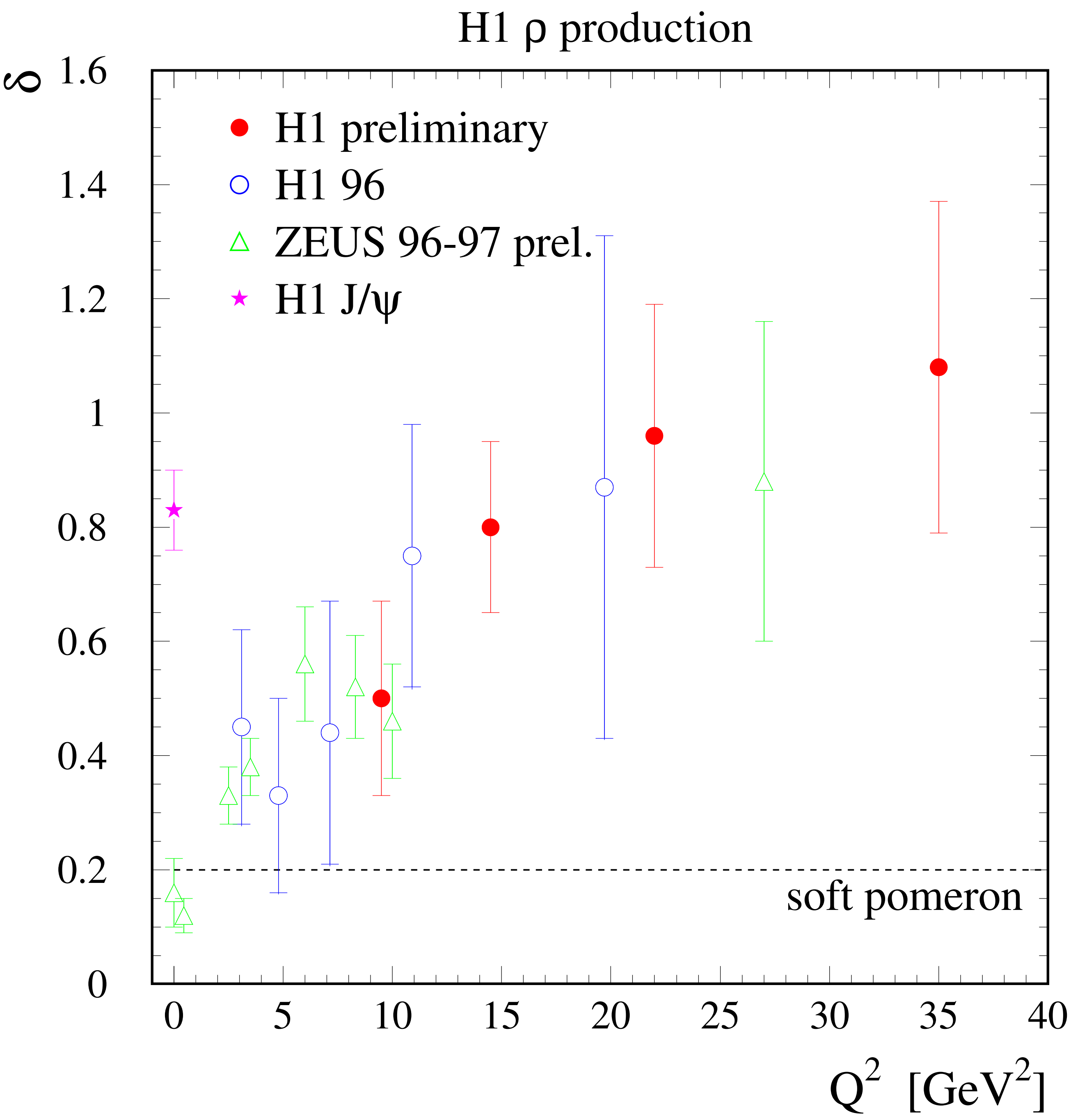
$$\text{Fit: } \sigma(W) \propto W^{\delta} \qquad \delta = 4\,\langle \alpha_{I\!P}(t) \rangle$$



$\Longrightarrow$ Slope becomes steeper with Q^2

δ AS A FUNCTION OF Q^2

$$\alpha_{I\!P}(0) = \frac{1}{4}\ [\ \delta - \alpha'_{I\!P}\ \langle|t|\rangle\ ]$$

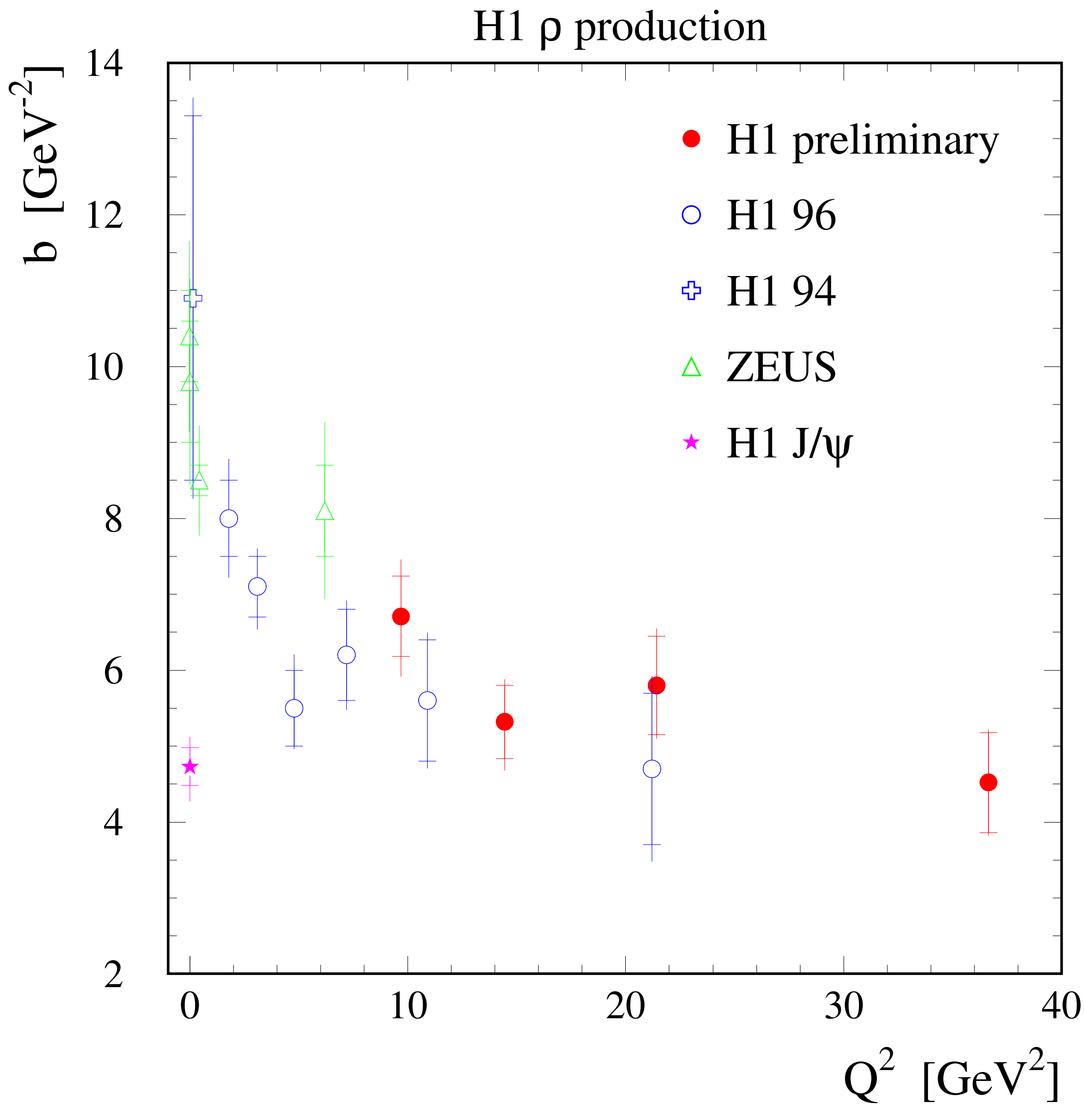


- Transition between soft and hard regimes
- $\delta_\rho\ (Q^2 >> 0) \longrightarrow \delta_{J/\psi}\ (Q^2 \approx 0)$

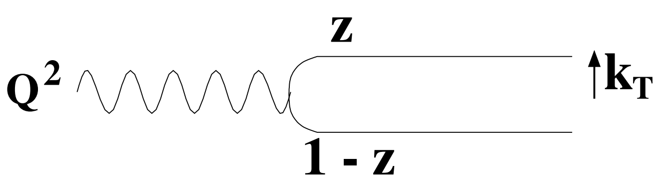
HIGH Q^2: t DEPENDENCE

$$\text{Fit: } \frac{d\sigma}{dt} \propto e^{-b|t|}$$

$$b \sim r^2_{\perp q\bar{q}} + r^2_{\perp proton}$$



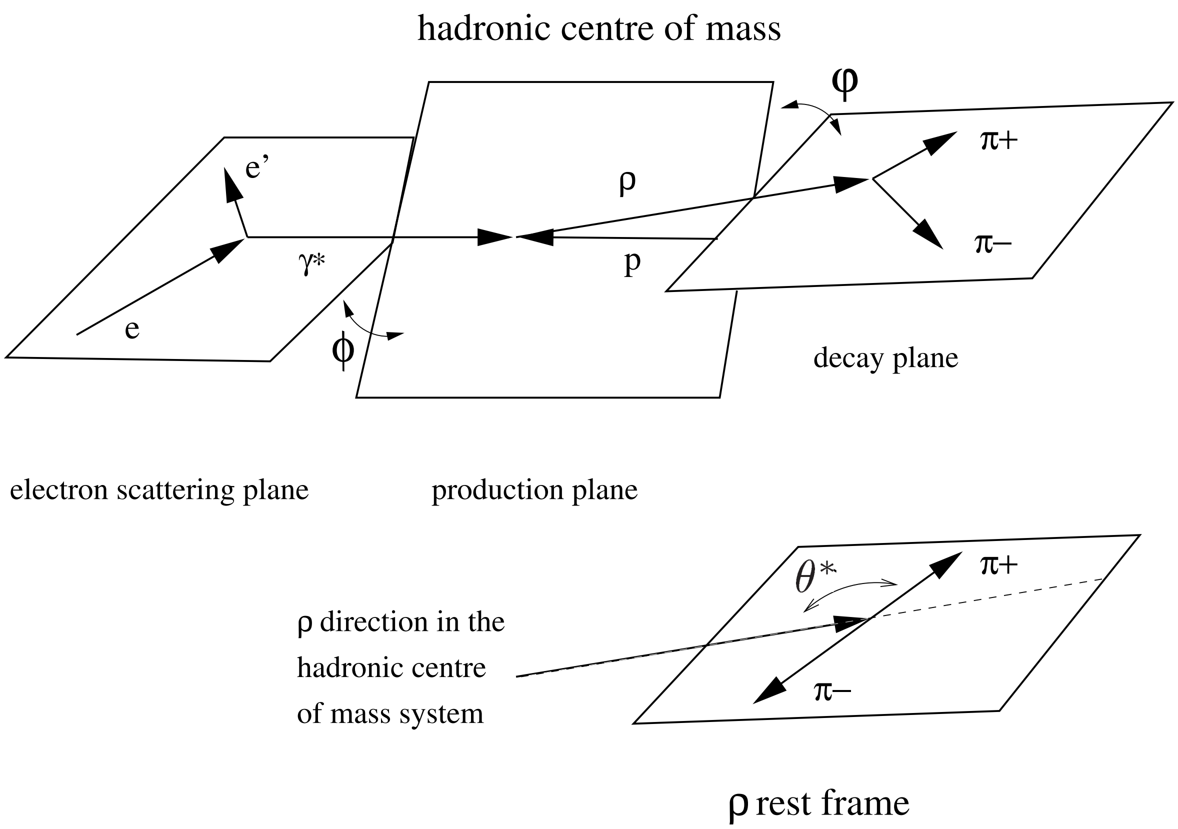
- Transverse size of $q\bar{q}$ decreases with Q^2



$$r^2_{\perp q\bar{q}} \sim \frac{1}{z(1-z)Q^2+m_q^2}$$

- $b_\rho\ (Q^2 >> 0) \longrightarrow b_{J/\psi}\ (Q^2 \approx 0)$

HIGH $|t|$ AND HIGH Q^2 : SPIN DENSITY MATRIX ELEMENTS



$$\theta^* \;,\; \Phi \;,\; \varphi \quad \Longleftrightarrow \quad \text{15 SDME} : r^{ij}_{kl} \propto T_{\lambda'_\rho \lambda'_\gamma} T_{\lambda_\rho \lambda_\gamma}$$

$$T_{\lambda_\rho \lambda_\gamma} \;:\; \text{helicity amplitudes}$$

No helicity flip: $T_{00} : \gamma_L \rightarrow \rho_L$

$T_{11} : \gamma_T \rightarrow \rho_T$

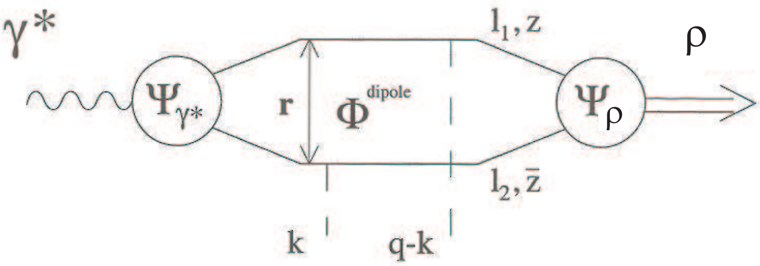
Single flip: $T_{01} : \gamma_T \rightarrow \rho_L$

$T_{10} : \gamma_L \rightarrow \rho_T$

Double flip: $T_{1-1} : \gamma_T \rightarrow \rho_T$

SDME: pQCD MODELS

Ivanov and Kirschner (hep-ph/9807324)



$$T \propto \Psi_{\gamma^*} \otimes \Phi^{dipole} \otimes \Psi_\rho$$

- $T_T \propto \frac{1}{z(1-z)}$

  $\Longrightarrow$ divergence (Non perturbative effects : $b_T > b_L$)

  $\longrightarrow G(x, \tilde{Q}^2) \sim (\frac{\tilde{Q}^2}{\tilde{Q}_0^2})^\gamma$

  where γ : anomalous gluon density dimension

  $\Longrightarrow$ $z = 1$, 0 non relevant

  $\Longrightarrow$ pQCD applicable to T_T

- 2 parameters :
  - $m_{q\bar{q}}$: effective quark pair mass
  - γ
- Scale $z(1-z)Q^2$ but data $\langle Q^2 \rangle = 5\ GeV^2$

SDME: pQCD PREDICTIONS

⇒ Hierarchy

$$|T_{00}| > |T_{11}| > |T_{01}| > |T_{10}| > |T_{1-1}|$$

⇒ t dependence

$$r^{04}_{00} \propto \frac{|T_{00}|^2+|T_{01}|^2}{N} \propto Cst(t)$$

$$r^{5}_{00} \propto \frac{1}{N}(T_{00}\ T^{\dagger}_{01}) \propto \sqrt{|t|}$$

$$r^{5}_{11} \propto \frac{1}{N}(T_{11}\ T^{\dagger}_{10} - T_{10}\ T^{\dagger}_{1-1}) \propto \sqrt{|t|}$$

$$r^{1}_{00} \propto \frac{1}{N}|T_{01}|^2 \propto -|t|$$

$$r^{1}_{11} \propto \frac{1}{N}(T_{11}\ T^{\dagger}_{1-1}) \propto |t|$$

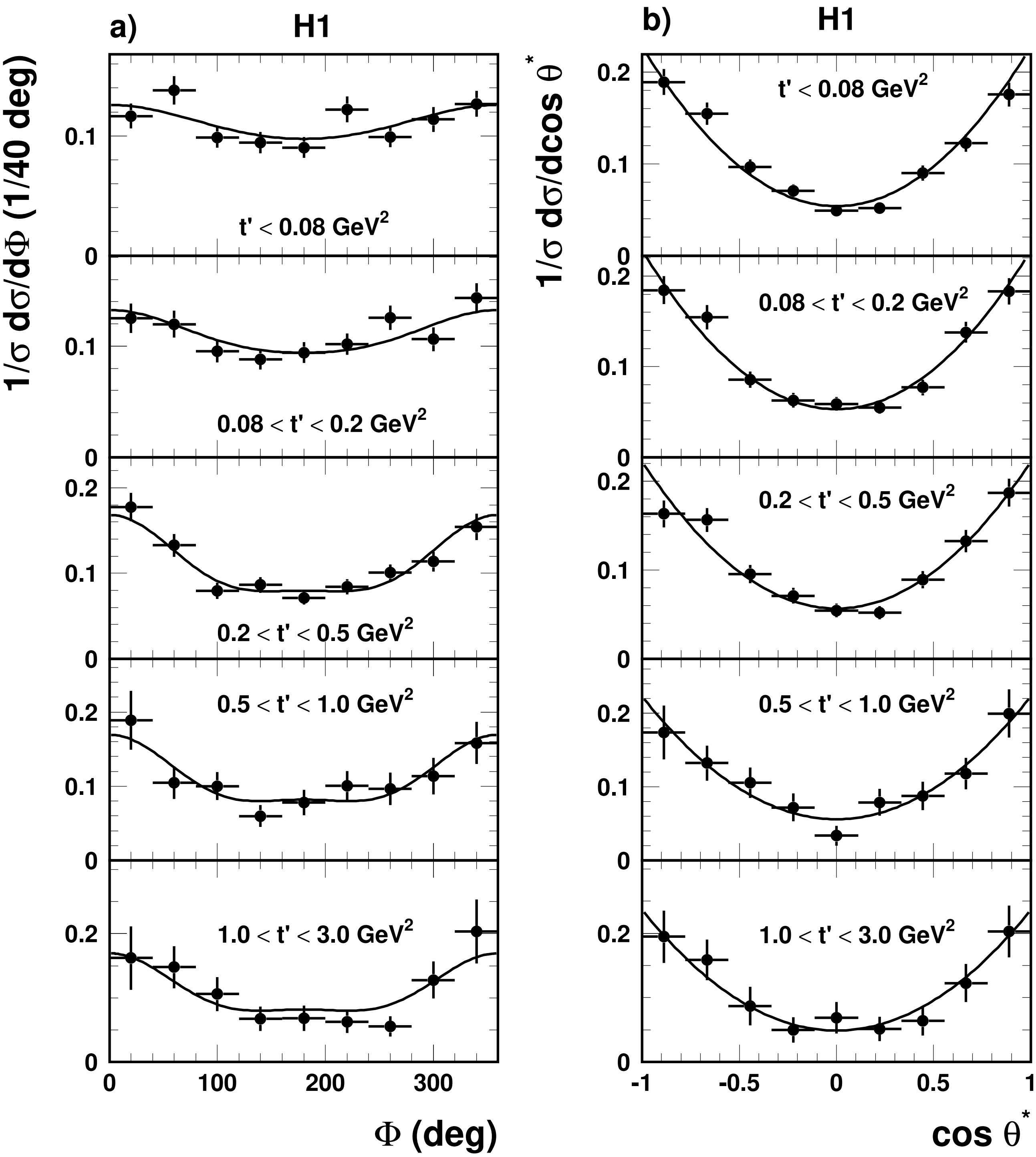
$$N = \sum_{i,j} |T_{ij}|^2 \qquad i = \lambda_\rho, j = \lambda_\gamma \quad = -1, 0, 1$$

N.B.: $\quad \mathrm{SCHC} \Longrightarrow r^5_{11} = r^5_{00} = r^1_{00} = r^1_{11} = 0$

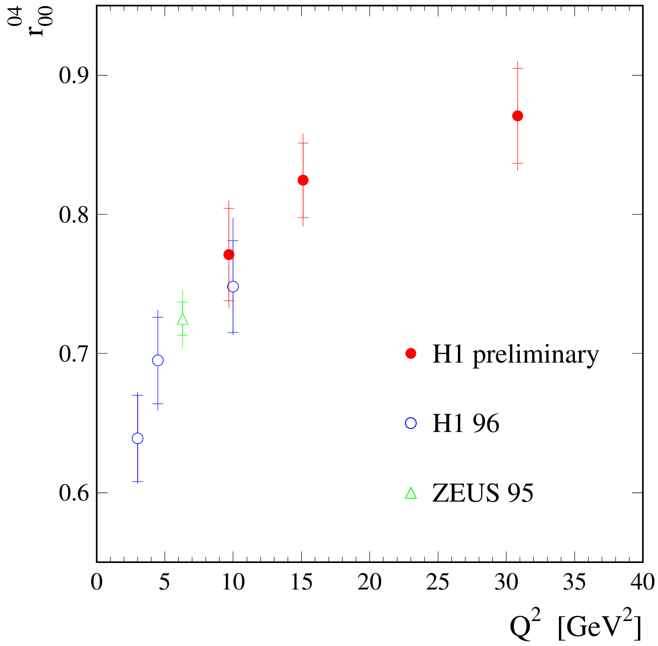
SDME

$$W(\cos\theta^*) \propto 1 - r^{04}_{00} + (3\ r^{04}_{00} - 1)\ \cos^2\theta^*$$

$$W(\Phi) \propto 1+\sqrt{2\epsilon(1+\epsilon)}(r^5_{00} + 2r^5_{11})\cos\Phi - \epsilon(r^1_{00} + 2r^1_{11})\cos 2\Phi$$



SDME : r_{00}^{04} and $R = \sigma_L/\sigma_T$



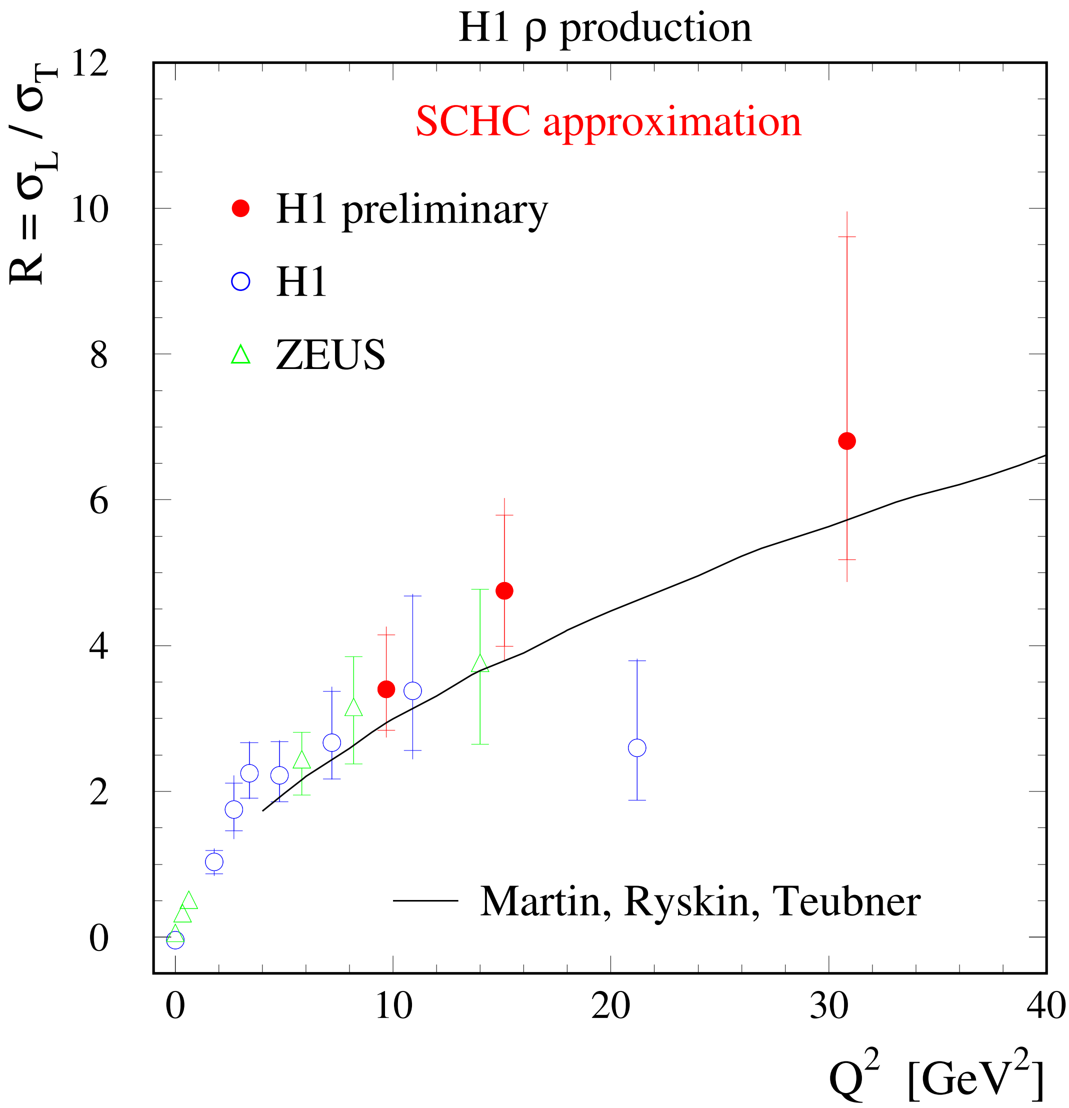
SCHC approximation :

$$R = \sigma_L/\sigma_T \simeq \frac{1}{\epsilon}\frac{r_{00}^{04}}{1-r_{00}^{04}}$$

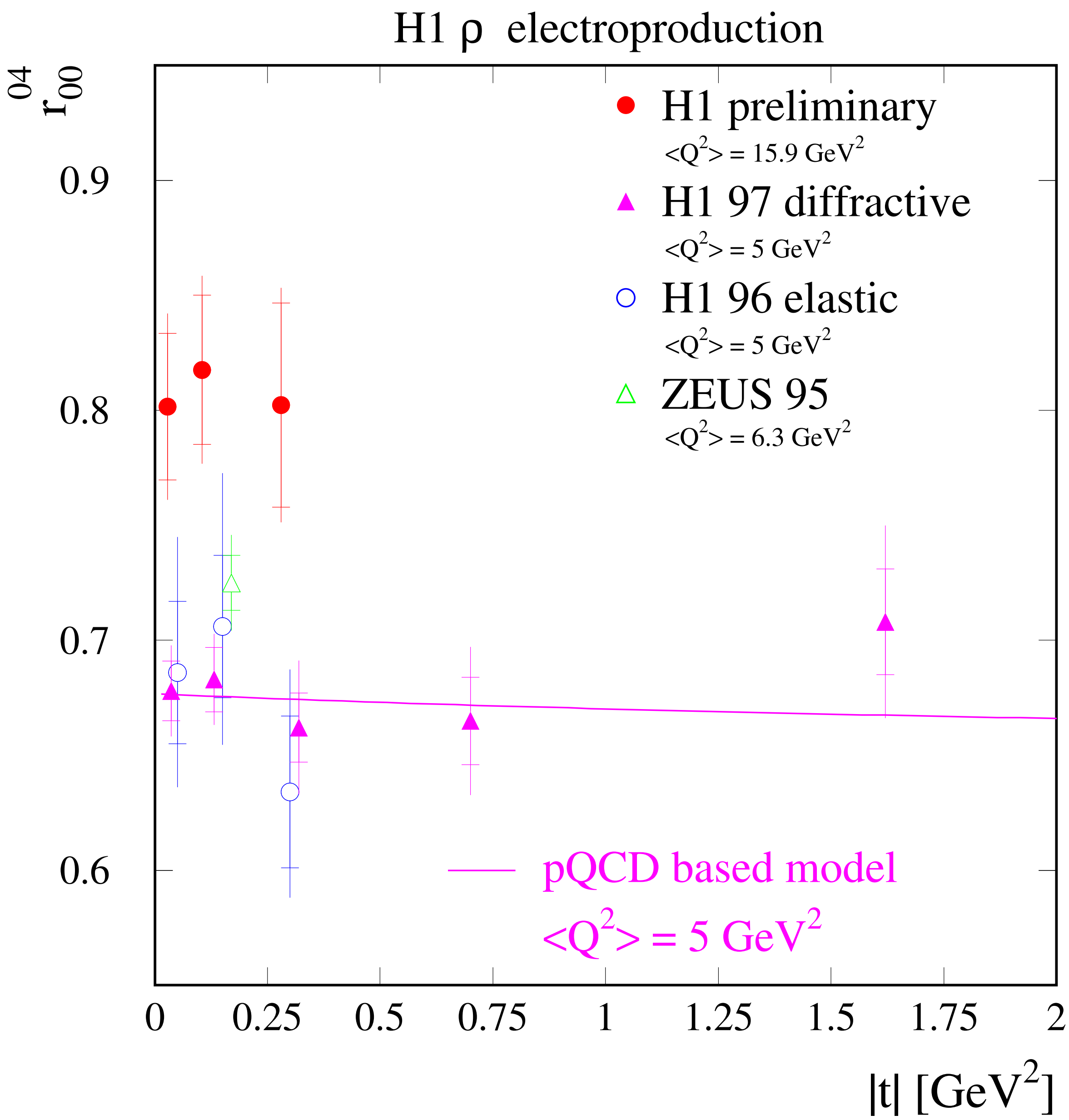
Martin & al. : Phys. Rev. **D55** (1997) 4329

$$R \simeq \frac{Q^2}{M^2}\left(\frac{\gamma}{1-\gamma}\right)^2 \quad ; \quad \gamma = \gamma(Q^2)$$

$\Longrightarrow$ Flattening



SDME: r_{00}^{04}



No t dependence

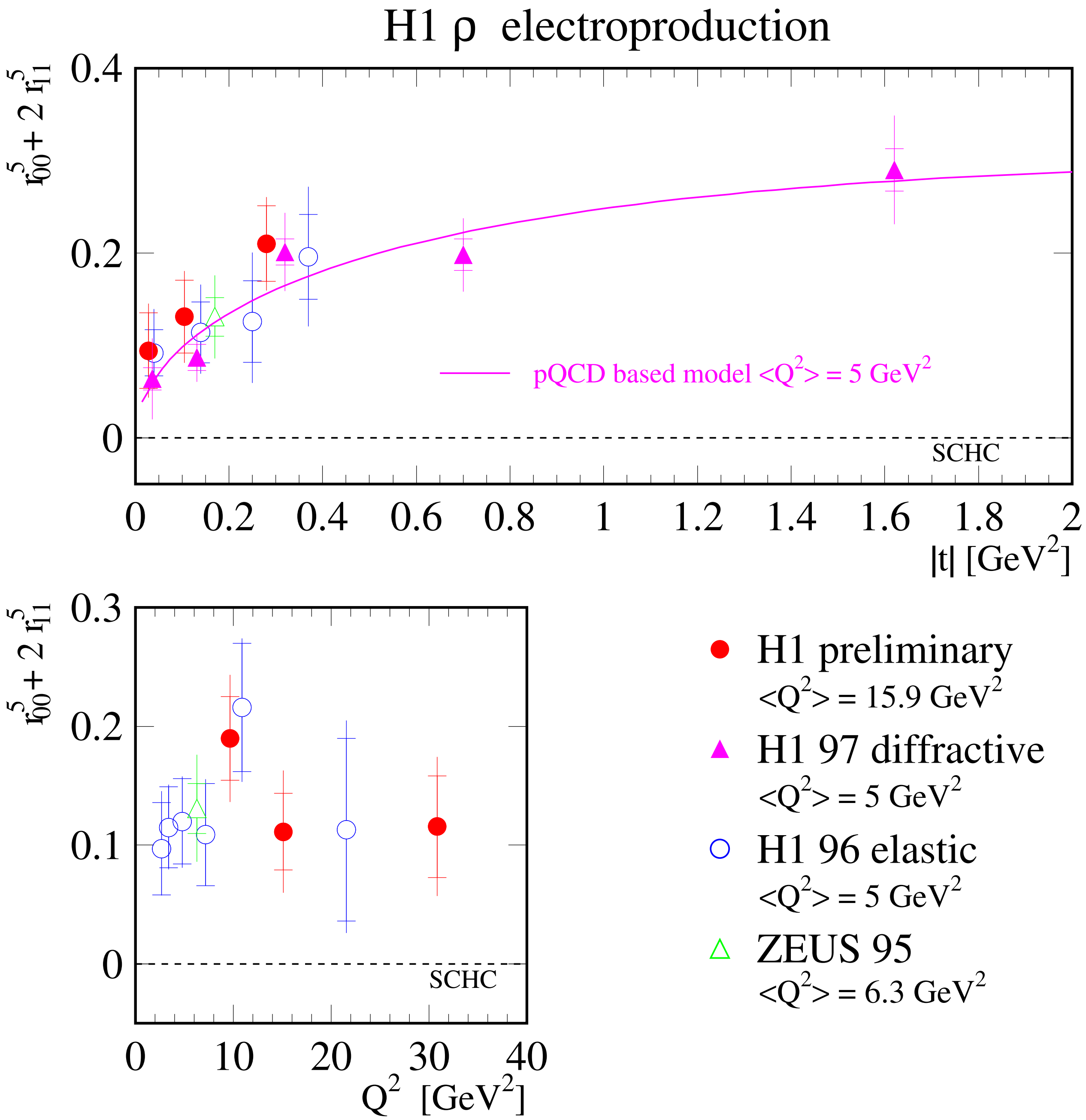
$\Longrightarrow R = \sigma_L/\sigma_T$ constant with t

$\Longrightarrow b_L \simeq b_T \simeq 5 - 6\ GeV^{-2}$

SDME: $r^5_{00} \; + \; 2 \; r^5_{11}$

$$r^5_{00} \propto \frac{1}{N}(T_{00} \; T^\dagger_{01}) \propto \sqrt{|t|}$$

$$r^5_{11} \propto \frac{1}{N}(T_{11} \; T^\dagger_{10} - T_{10} \; T^\dagger_{1-1}) \propto \sqrt{|t|}$$



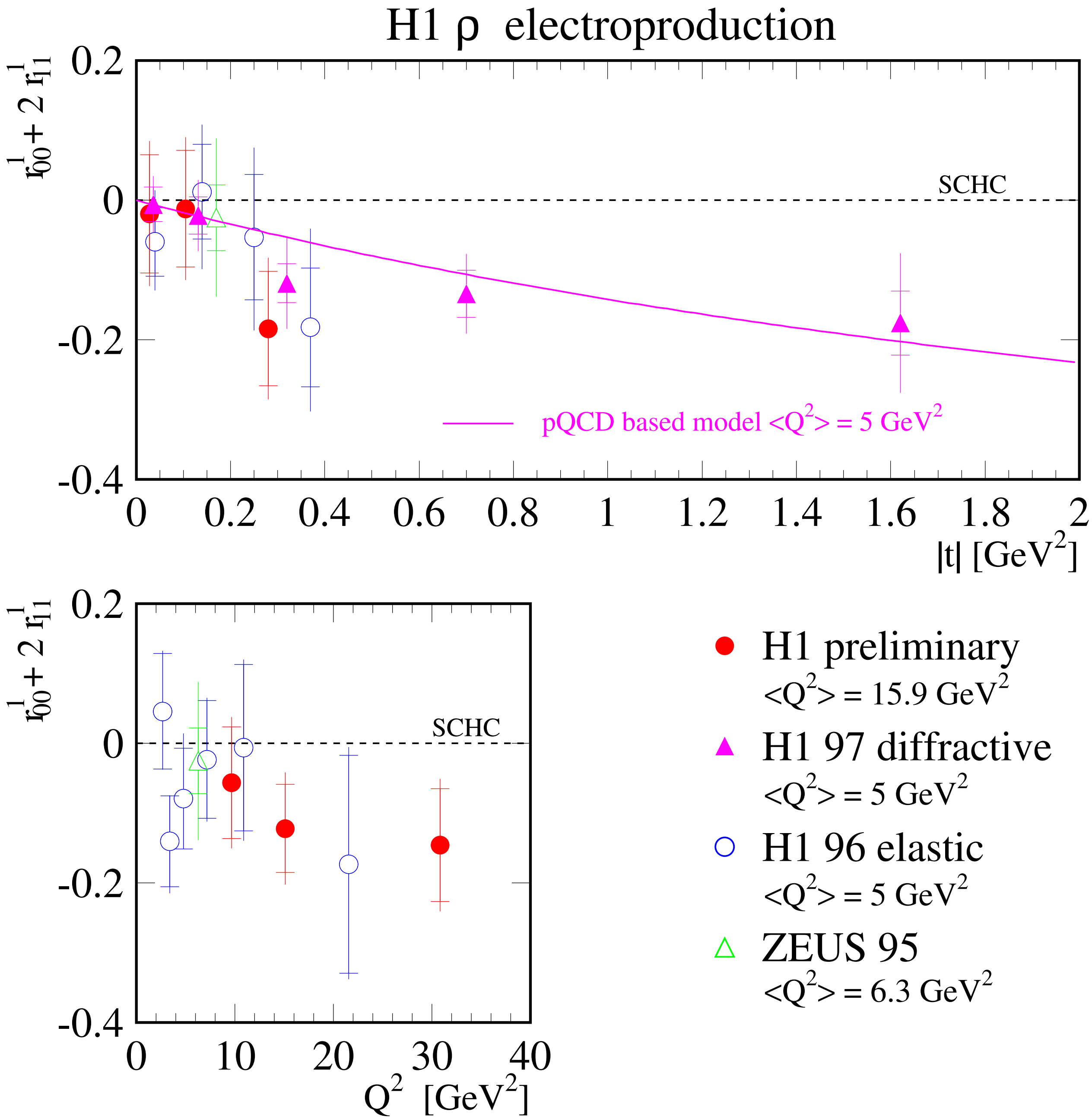
Significant SCHC violation

Proportional to $\sqrt{|t|}$, as expected

SDME: $r^1_{00} + 2\ r^1_{11}$

$$r^1_{00} \propto \frac{1}{N}|T_{01}|^2 \propto -|t|$$

$$r^1_{11} \propto \frac{1}{N}(T_{11}\ T^\dagger_{1-1}) \propto |t|$$



T_{01} (single flip) dominant

Proportional to $|t|$, as expected

CONCLUSIONS

- High Q^2 :
  - High precision reached for ρ meson electroproduction
  - Transition between soft Pomeron at low Q^2 to hard (pQCD) dependence at large Q^2
  - At high Q^2, W and t ρ dependences become similar to J/Ψ ones
- Spin Density Matrix Elements :
  - r_{00}^{04} consistent with no t dependence $\Longrightarrow b_L \simeq b_T$
  - Hierarchy : $|T_{00}| > |T_{11}| > |T_{01}|$
  - $r_{00}^{5} \propto \sqrt{|t|}$ and $r_{00}^{1} \propto |t| \Longrightarrow T_{01}/T_{00} \propto \sqrt{|t|}$

$\Longrightarrow$ Agreement with pQCD calculations