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Proton Dissociative ρ° Electroproduction at HERA

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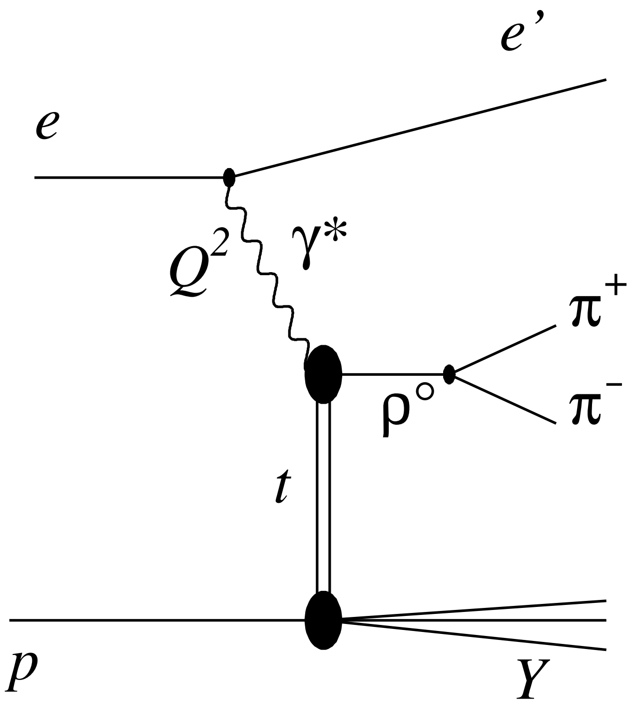
- Introduction
- Data Selection
- $\pi^+\pi^-$ Mass Spectrum
- t, Q^2 and W Dependences
- Angular Dependences
- Summary



Previous H1 work: $7 < Q^2 < 35 \text{ GeV}^2$

$t' < 0.5 \text{ GeV}^2$

Zeit.Phys. C75 (1997) 607

Present analysis: $1.5 < Q^2 < 30 \text{ GeV}^2$

$t' < 1.5 \text{ GeV}^2$

Main Interest here:

Compare with

Elastic ρ° electroproduction $1 < Q^2 < 60 \text{ GeV}^2$

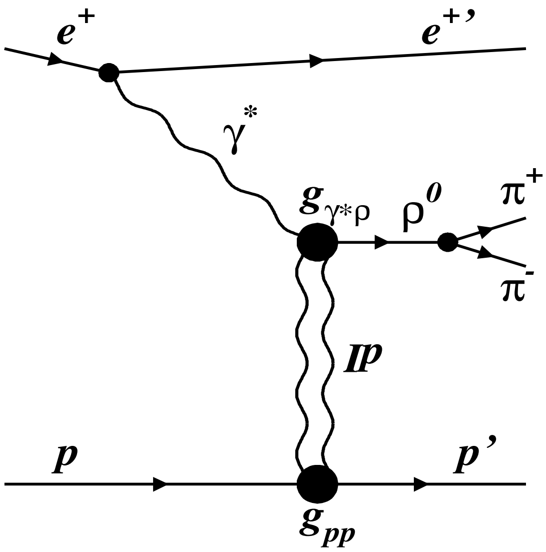
using previous H1 work $t' < 0.5 \text{ GeV}^2$

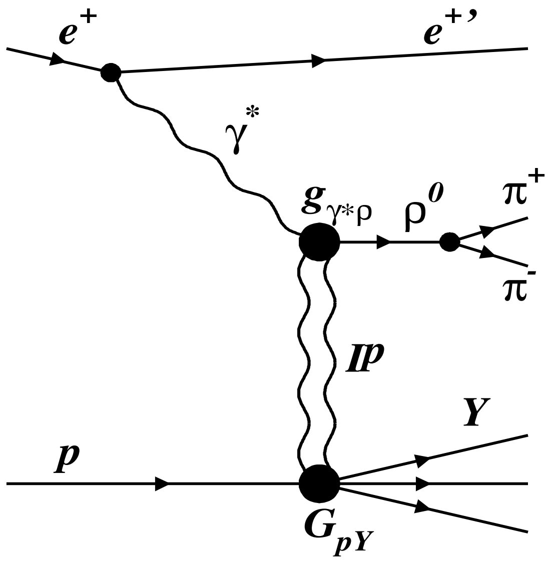
Eur.Phys.J. C13 (2000) 371

$$t' = |t| - |t|_{min}$$
$$\langle |t|_{min} \rangle \simeq 0.04 \text{ GeV}^2$$
$$t' \simeq P_t^2(e^+, \pi^+\pi^-)$$

$\gamma^* p \rightarrow \rho^\circ Y$ Introduction

Elastic **proton dissociative**





Cross Section Ratio$^{(\star)}$ and Vertex Factorisation

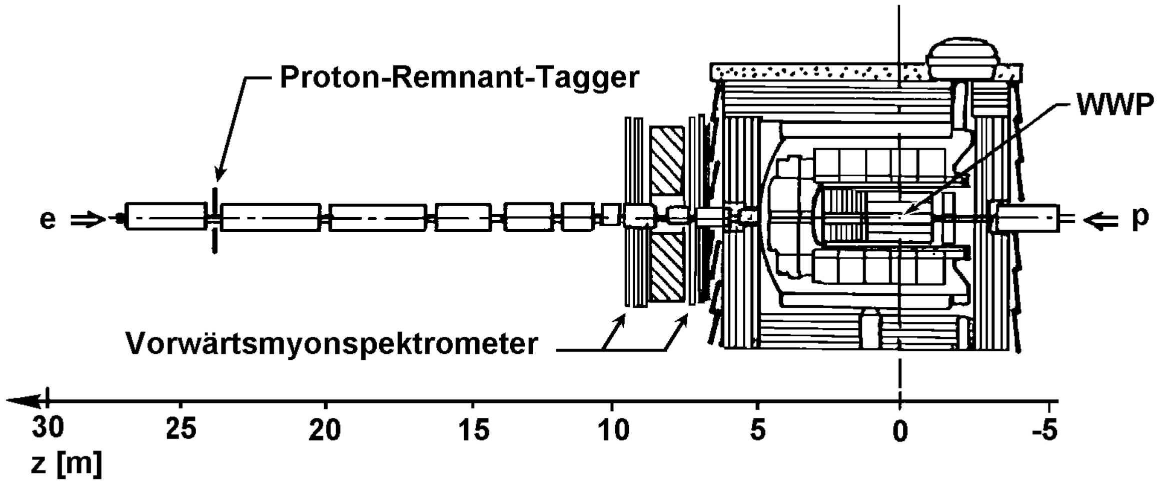
$$\frac{d^3\sigma_{pdiss} / d\,t\,dM_Y^2\,d\lambda}{d^2\sigma_{elastic} / d\,t\,d\,\lambda} \propto \left(\frac{g_{\gamma^*\rho}(t, Q^2, \lambda)\; G_{pY}(t, M_Y)}{g_{\gamma^*\rho}(t, Q^2, \lambda)\; g_{pp}(t)} \; \frac{(W^2/M_Y^2)^{\alpha(t)-1}}{(W^2/W_0^2)^{\alpha(t)-1}} \right)^2$$

$$= f(t, M_Y)$$

Expect: for given t and M_Y
the same W-, Q^2- and angular dependence
in proton dissociative and elastic processes

Vertex Factorisation hypothesis previously tested (SPS)
Found valid to $\sim$ 20 % accuracy

$(\star)$ The measured proton dissociative cross sections are in praxis integrated over M_Y and are quoted for the nominal acceptance $(M_Y/W)^2 < 0.05$.
The average decreasing correction is $\sim 8\%$



$e^+ + p$ (27.5 x 820 GeV) 1996 data 4.3 pb^{-1}

$25 < W < 150$ GeV $1.5 < Q^2 < 30$ GeV^2

- Two charged tracks $(\pi^+\pi^-)$
- $p_t > 100$ MeV
- $20^\circ < \theta < 160^\circ$
- Common vertex in I. R.

- e^+ in BDC / SpaCal
- $E_{e^+} > 17$ GeV

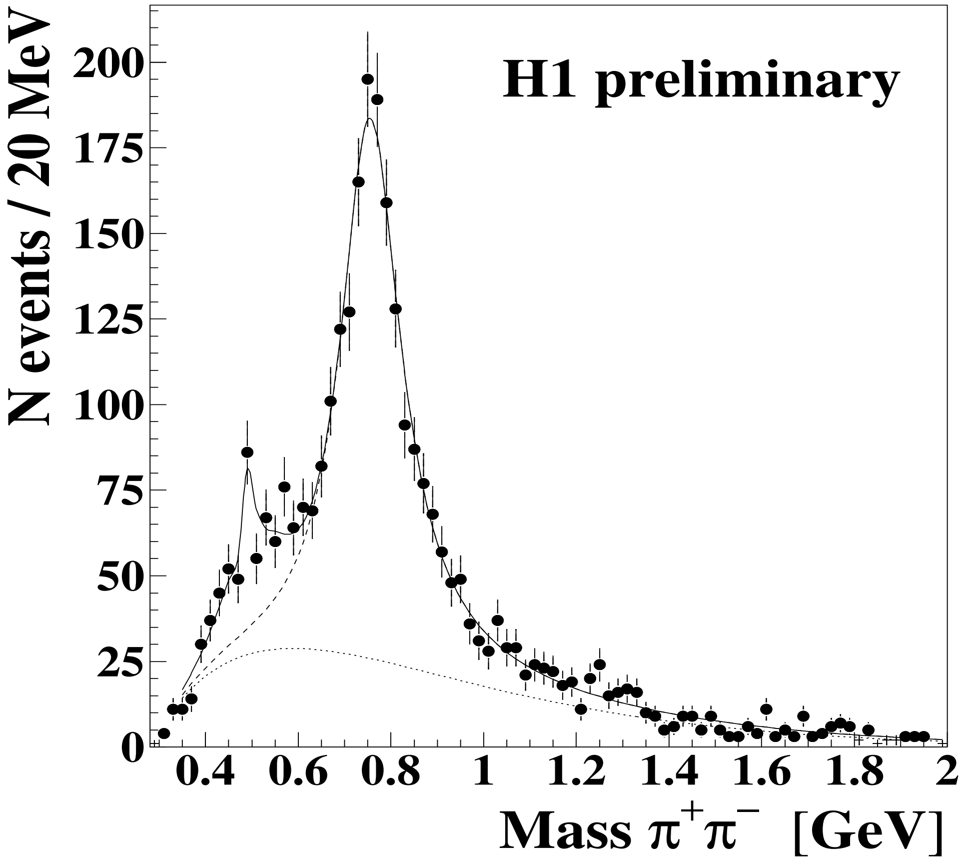
- No other track, $10^\circ < \theta < 170^\circ$
- No Calo Energy, $E_{clus} > 0.5$ GeV, $\eta < 2.7$
- Background cuts

- LAR Energy, $E_{clus} > 0.5$ GeV, $\eta > 2.7$
- ≥ 3 FMD hit pairs
- ≥ 1 PRT hits

P-Diss. Sample: Any of these
Elastic Sample: None of these

BUT: If $t' > 0.6$ GeV^2
and only PRT hits
$\Rightarrow$ Elastic Sample!

$\gamma^* p \rightarrow \rho^\circ Y$ **Mass Distribution**



$$f_\rho \mathrm{BW}_\rho(m_{\pi\pi}, \mathrm{M}_\rho, \Gamma_\rho)\left(\frac{\mathrm{M}_\rho}{m_{\pi\pi}}\right)^{n_{RS}}$$

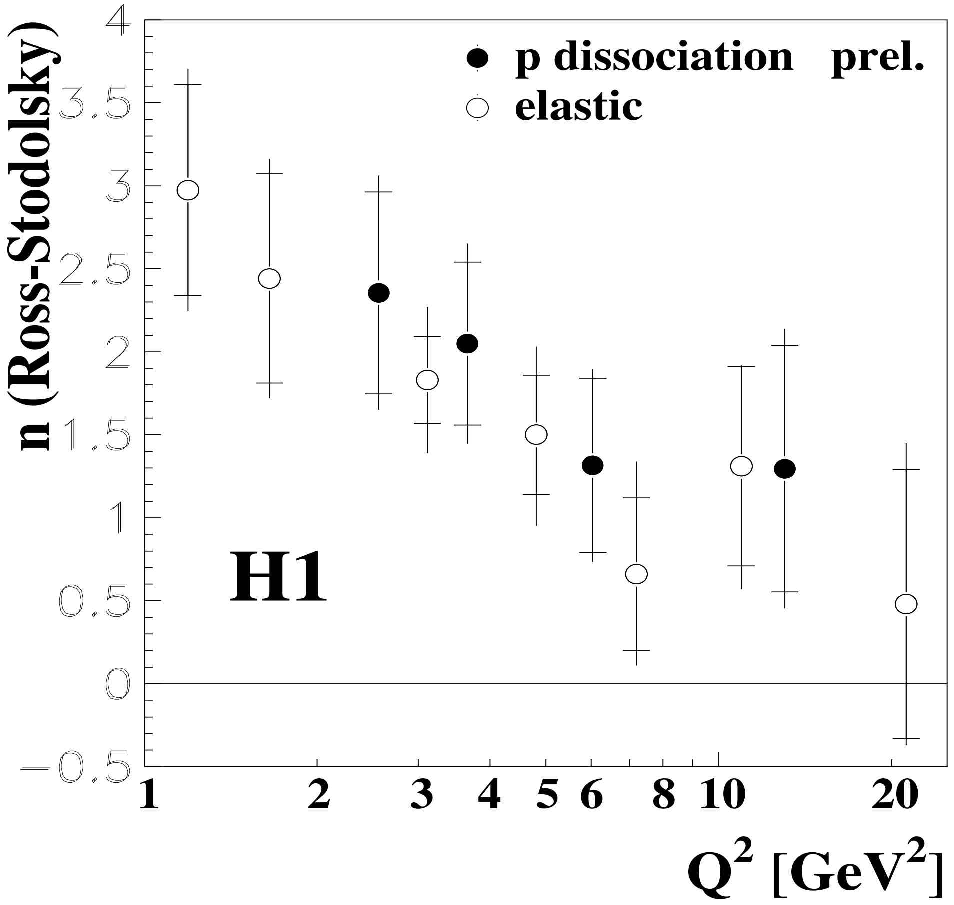
$$+ f_{bgr}(m_{\pi\pi} - 2m_\pi)e^{-\alpha_1 m_{\pi\pi}} + f_\omega \mathrm{G}_\omega + f_\phi \mathrm{G}_\phi$$

Background: exclusive resonance electroproduction (ω and ϕ) as well as non-resonant

Good Fit: P-wave Breit-Wigner, including Skewing, and background terms

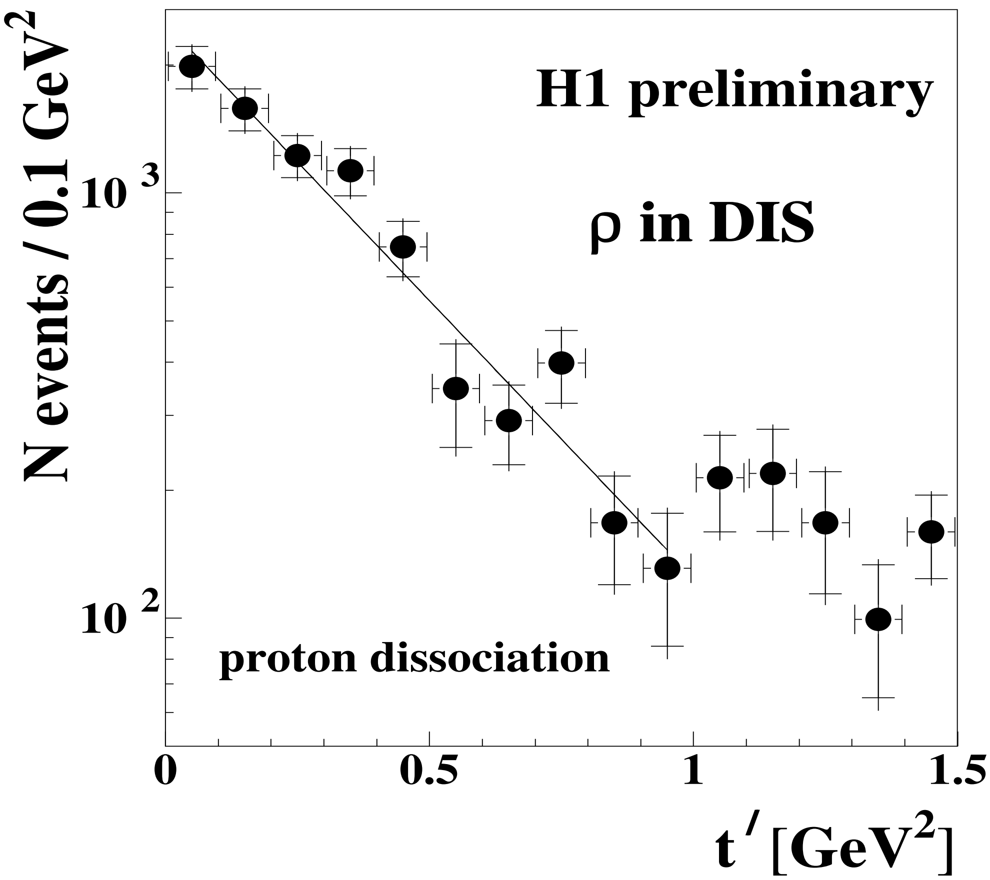
$\boxed{1773 \pm 153 \quad \rho \text{ events}}$

$\gamma^* p \rightarrow \rho^\circ Y$ **Skewing**



Skewing effect: **significant in low Q^2 region**
decreases with increasing Q^2

$$\langle n_{RS} \rangle = 1.8 \pm 0.8$$

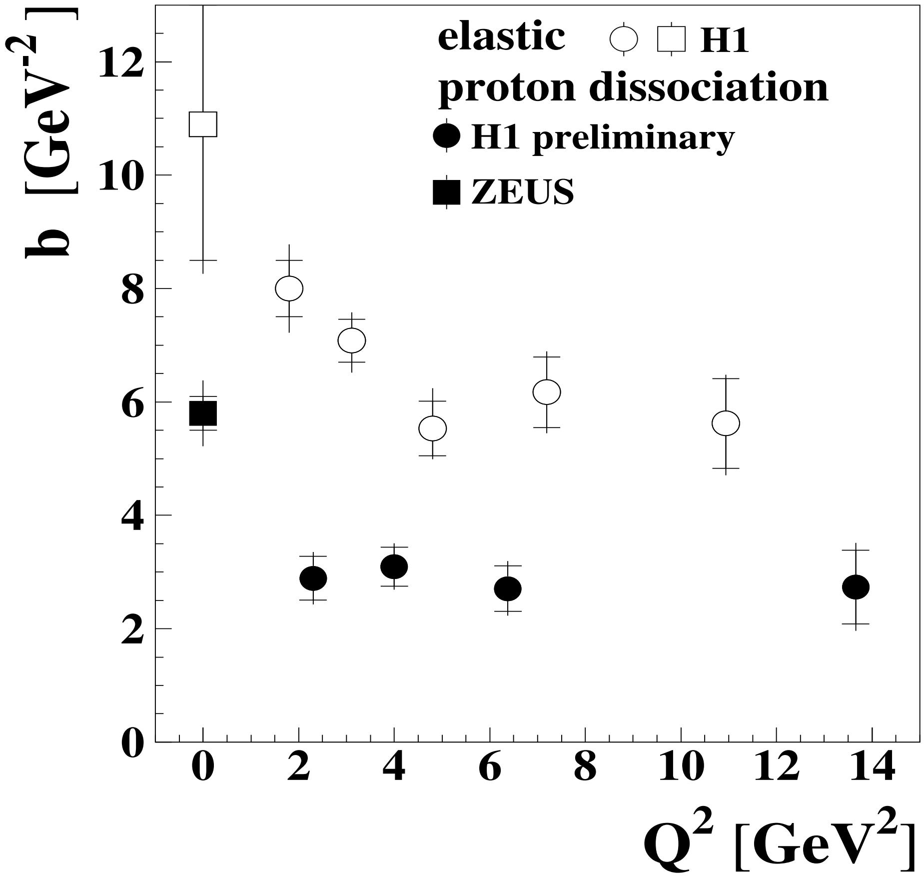


Fully corrected data

Fit to
$$\frac{d\sigma(ep)}{dt'} \propto \frac{dN}{dt'} \propto e^{-bt'}$$

$$\boxed{b_{pdiss} = 3.00 \pm 0.19^{+0.16}_{-0.14}\ \mathrm{GeV}^{-2}}$$

$\gamma^* p \rightarrow \rho^\circ Y$ **b Slope**



$\mathbf{b}_{\mathrm{pdiss.}}(Q^2 > 0)$ $\propto$ independent of $\mathbf{Q}^2$

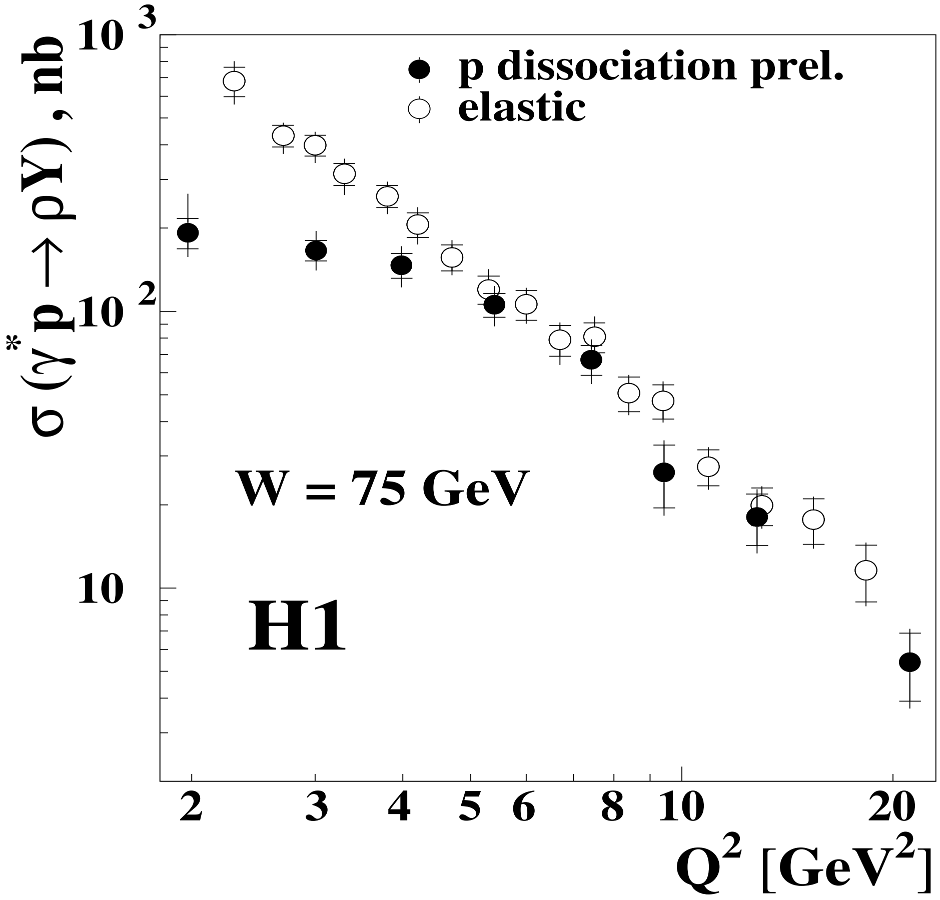
$\mathbf{b}_{\mathrm{pdiss.}}(Q^2 > 0)$ significantly lower than $\mathbf{b}_{\mathrm{pdiss.}}(Q^2 = 0)$

$\mathbf{b}_{\mathrm{pdiss.}}$ significantly lower than $\mathbf{b}_{\mathrm{elastic}}$

***b* is related to the radii of the scattering particles**

$$b \propto R_p^2 \oplus R_{q\bar{q}}^2 \quad \Rightarrow$$

Scattering off a proton fragment !



Cross sections interpolated to $W = 75$ GeV

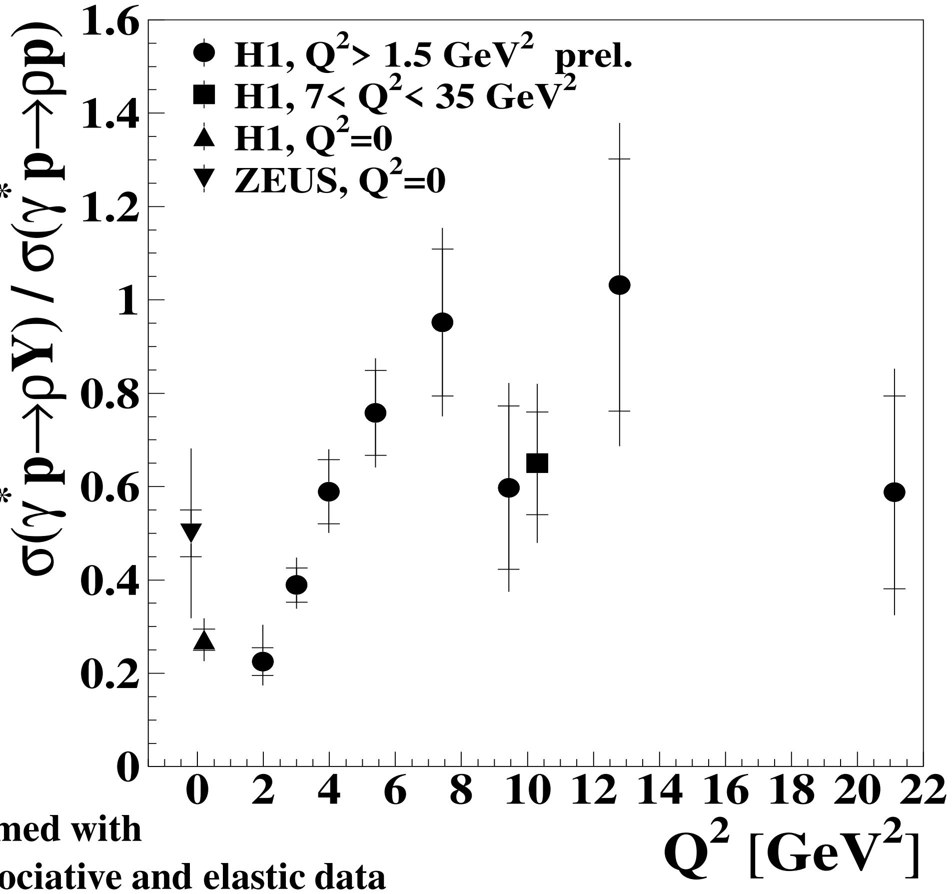
integrated within $t' < 1.5$ GeV^2

p-diss. and elastic cross sections similar for $Q^2 \gtrsim 5$ GeV^2

p-diss. cross section significantly lower for $Q^2 \lesssim 5$ GeV^2

Ratio $\Rightarrow$

$\gamma^* p \rightarrow \rho^\circ Y$ Ratio p-Diss. / Elastic



Ratio formed with
H1 p-dissociative and elastic data
from present analysis

Strong rise for $Q^2 \lesssim 5$ GeV^2

Effect survives all cross-checks:

Change of W-range and other selection criteria

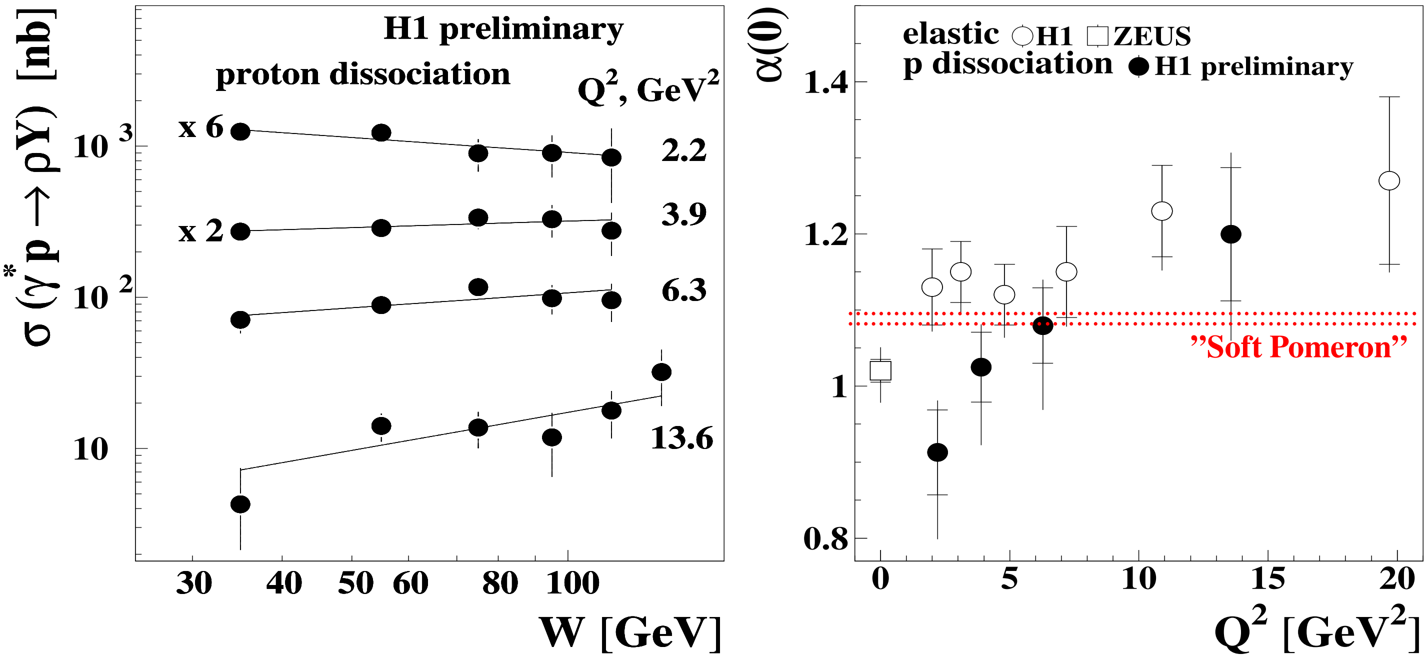
Use of raw numbers of events for the Ratio

Effect cannot be due to the t' integration:

b slope $\sim$ constant with Q^2

Indication of Breaking of Vertex Factorisation !

$\sigma(\gamma^* p \rightarrow \rho^\circ Y)$ W and Q^2 Dependence



Cross section integrated over t′

In each Q^2 bin, fit $\sigma_{\gamma^* p} \propto W^\delta$

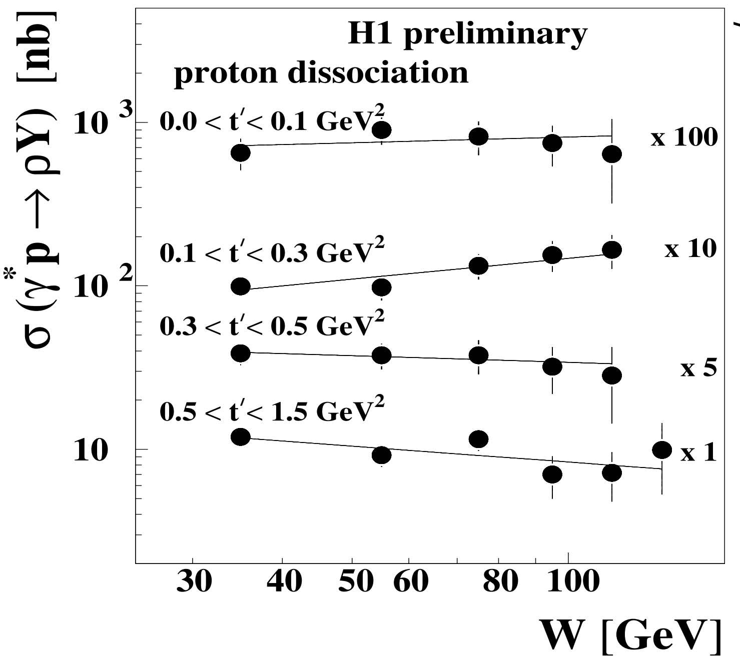
Effective exchange trajectory $\alpha(t)$

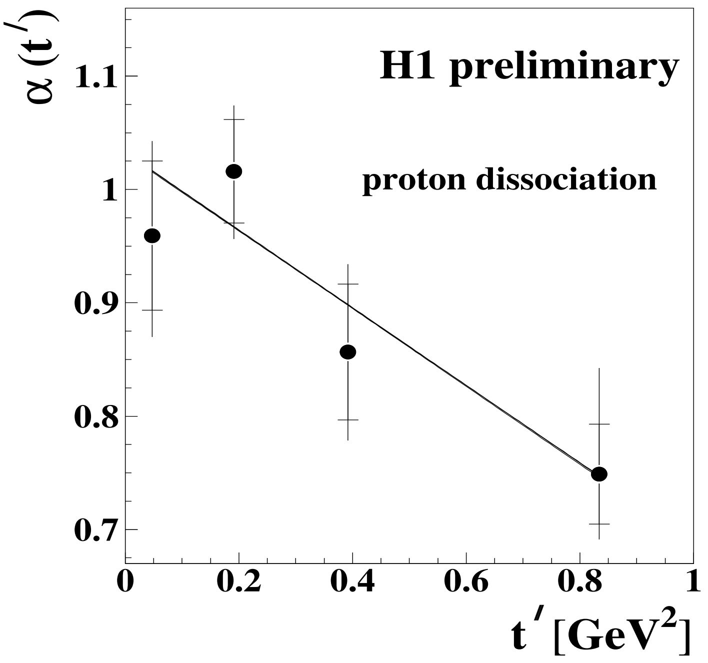
$$\delta(Q^2) = 4[\alpha(0) - 1 + \alpha'/b(Q^2) + \Delta_{M_Y}]$$

α' set to $-0.25\ \mathrm{GeV}^{-2}$
$\Delta_{M_Y} = 0.09 \pm 0.01$ (known from MC sim.)

Indication that $\alpha(0)$ rises with Q^2
sign of transition from "soft" nonperturbative to "hard" perturbative regime ?

$\sigma(\gamma^* p \rightarrow \rho^\circ Y)$ W and t' Dependence





Cross section integrated over Q^2

In each bin of t', fit $\sigma_{\gamma^* p} \propto W^\delta$

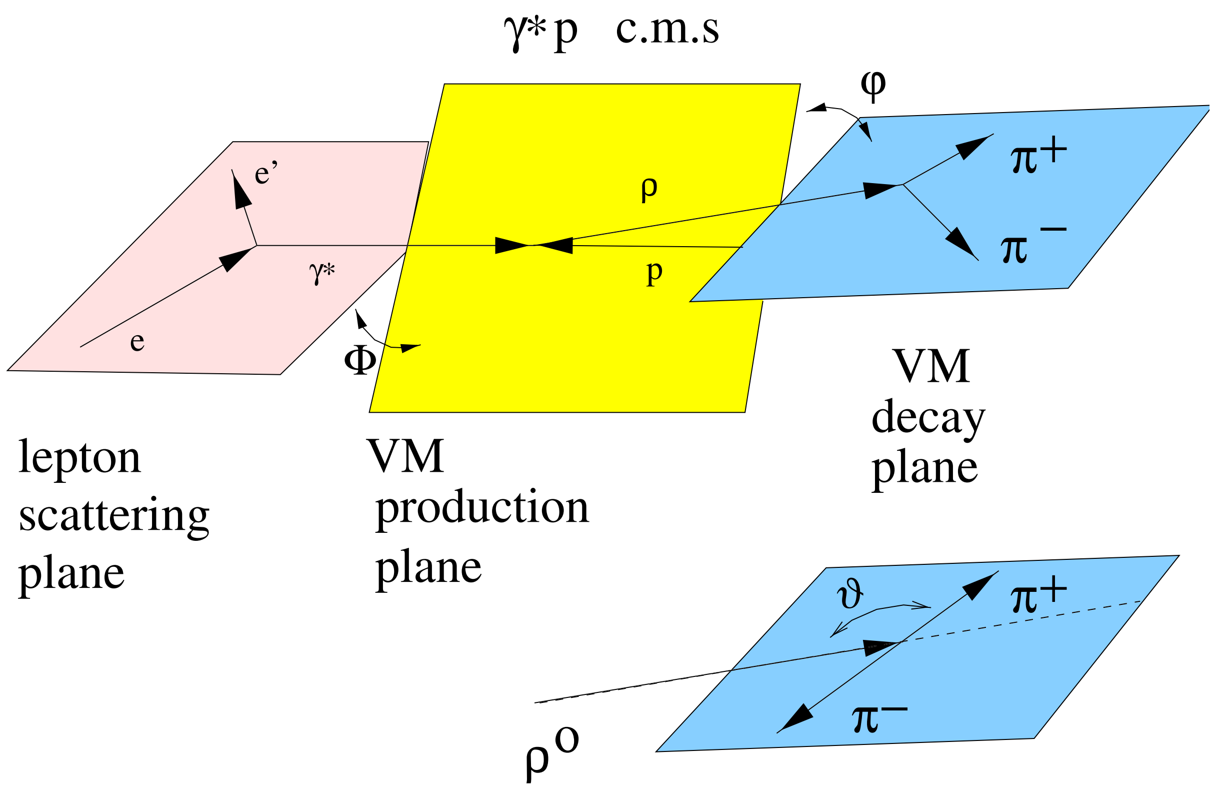
Effective exchange trajectory $\alpha(t')$

$$\delta = 4[\alpha(t') - 1 + \Delta_{M_Y}]$$

Fit $\alpha(t') = \alpha(0) + \alpha' t'$

$$\boxed{\begin{aligned} \alpha(0) &= 1.03 \pm 0.05 \pm 0.04 \\ \alpha' &= -0.34 \pm 0.08^{+0.12}_{-0.08} \text{ GeV}^{-2} \end{aligned}}$$

$\gamma^* p \;\rightarrow\; \rho^\circ Y$ Angular Dependences



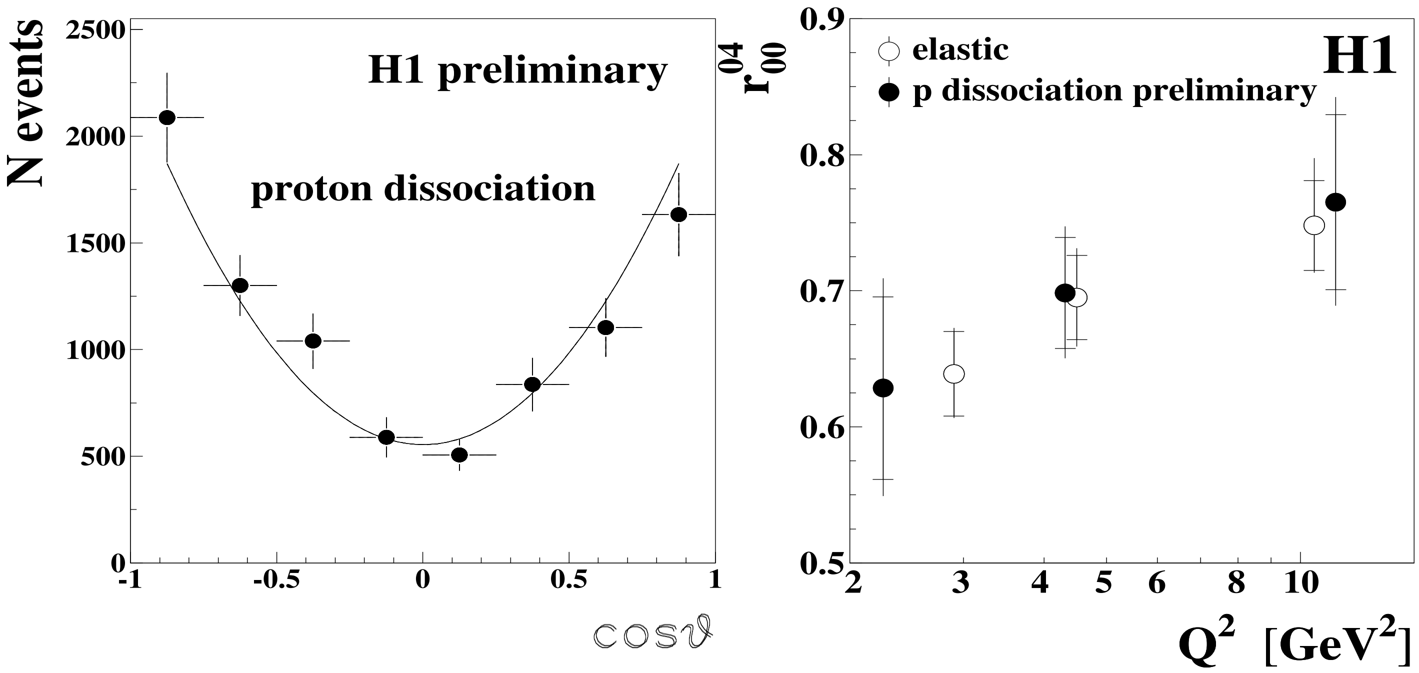
Use Helicity Frame

Decay angular distribution $W(\cos\vartheta, \varphi, \Phi)$**,**
15 indep. combinations of spin-density matrix elements

SCHC, NPE: Only 5 combinations $\neq 0$

In Principle: can determine all 15 combinations from data

But: presence of background in p - Dissociation
$\Rightarrow$ **study 1-dimensional distributions**



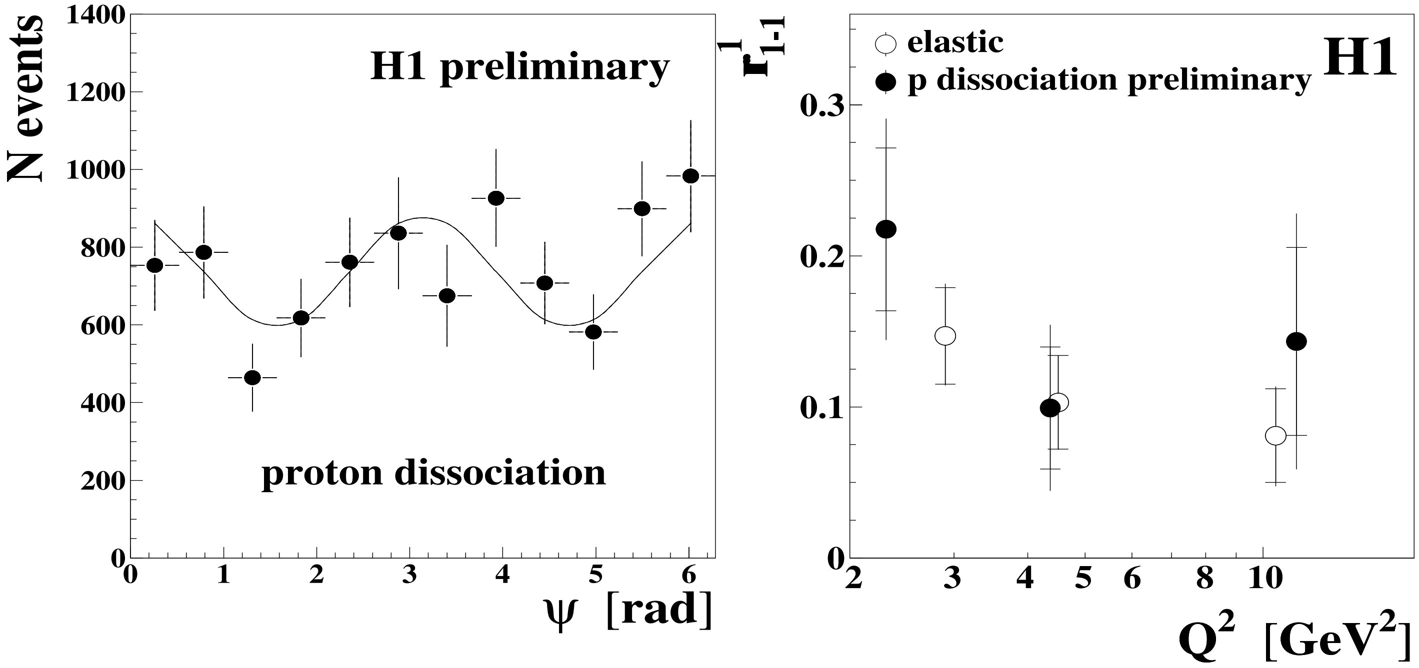
$$d\,N/d\cos\vartheta \;\propto\; 1 - r_{00}^{04} + (3\,r_{00}^{04} - 1)\cos^2\vartheta$$

r_{00}^{04} : **probability to produce longitudinal ρ°**

(from either transverse or longitudinal γ^*)

Fraction of long. polarised ρ° mesons increases with Q^2

$\gamma^* p \rightarrow \rho^\circ Y$ Ψ Dependence



$$\Psi = \Phi - \varphi$$

SCHC approximation:

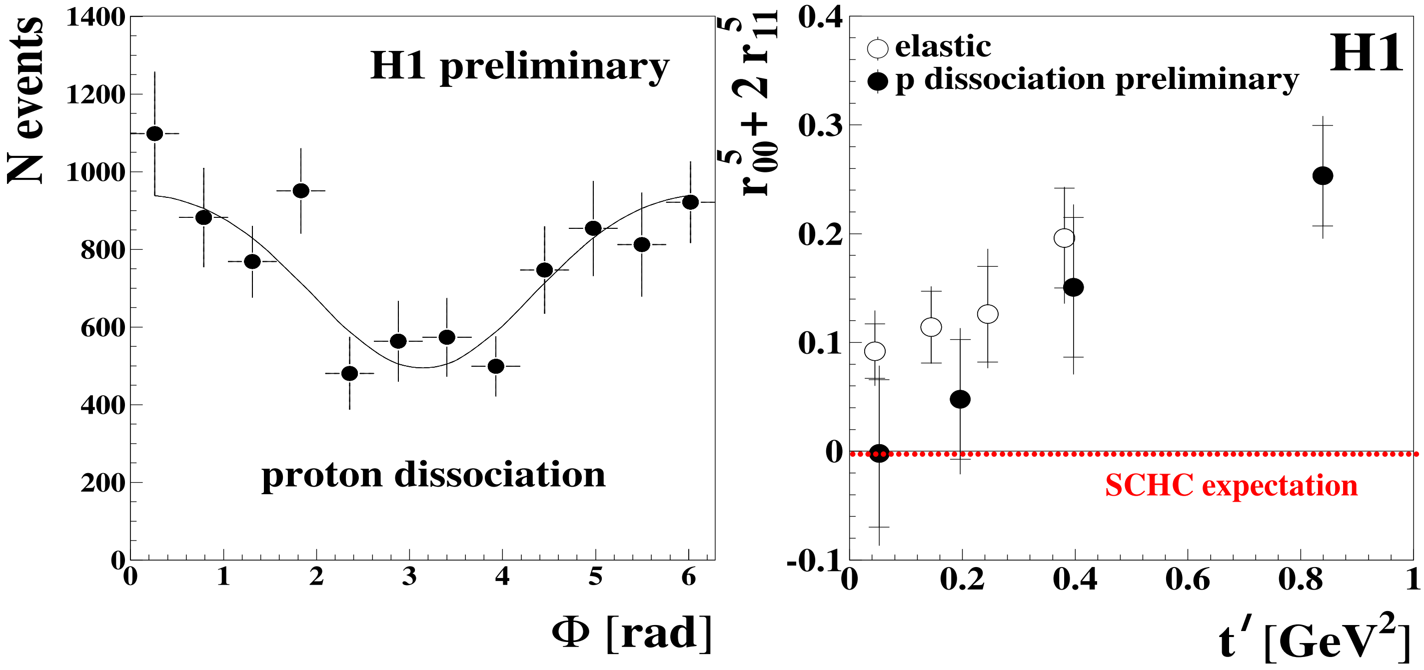
$$dN/d\Psi \propto (2\pi)^{-1} (1 + 2\epsilon r^1_{1-1} \cos 2\Psi)$$

(γ^* polarisation parameter $\epsilon \sim 0.99$)

SCHC and NPE: $r^1_{1-1} = 1/2\,(1 - r^{04}_{00})$

confirmed by data

$\gamma^* p \rightarrow \rho^\circ Y$ — Φ Dependence



$$dN/d\Phi \;\propto\; 1 \;+\; \sqrt{2\epsilon(1+\epsilon)}\,(r^5_{00} + 2r^5_{11})\;\cos\Phi$$
$$-\;\; \epsilon\;(r^1_{00} + 2r^1_{11})\;\cos 2\Phi$$

Significant SCHC breaking observed increasing with t', reaching $\sim$ 20%

pQCD: expect $r^5_{00} \neq 0$ and r^5_{00} dominant over r^5_{11}
Experiment: r^5_{11} found small in elastic case

$r^5_{00} \sim \sqrt{2\,R}/(1+\epsilon R)\,|T_{01}|/|T_{11}| \qquad R = \sigma_L/\sigma_T$
T_{01}: Amplitude for a transverse photon to produce a longitudinal ρ°

S U M M A R Y

Proton dissociative ρ° electroproduction studied, for
$1.5 < Q^2 < 30\ \mathrm{GeV}^2, \quad 25 < W < 150\ \mathrm{GeV}$
$t' < 1.5\ \mathrm{GeV}^2$
Compared with elastic ρ° electroproduction

- **Skewing of ρ° shape decreases with Q^2**
- **t' distribution well approximated by an exponential form**
  - ▷ $b_{pdiss} = 3.00 \pm 0.19^{+0.16}_{-0.14}\ \mathrm{GeV}^{-2}$
  - ▷ **b_{pdiss} below $b_{elastic}$ by $3 - 4\ \mathrm{GeV}^{-2}$**
  - ▷ **b_{pdiss} has flat Q^2 dependence,**
    but lower than photoproduction value by $2 - 3\ \mathrm{GeV}^{-2}$
- **Q^2 dependence of σ_{pdiss} and $\sigma_{elastic}$ similar, for $Q^2 \gtrsim 5\ \mathrm{GeV}^2$**

  Ratio $\sigma_{pdiss}/\sigma_{elastic}$ rises steeply with Q^2, for $Q^2 \lesssim 5\ \mathrm{GeV}^2$
  Indication of Vertex Factorisation Breaking
- **Power law fit of W dependence of cross section, in bins of Q^2 and t'**
  - ▷ **Effective exchange trajectory extracted**
  - ▷ **Indication that**
    Intercept $\alpha(0)$ rises with Q^2
    $\alpha(t')$ decreases with t' (shrinkage)
- **Spin-density matrix element combinations determined**
  found to agree with elastic case.

  In particular, significant violation of SCHC seen,
  increasing with t'
  and with magnitude similar to the elastic case