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Diffractive Vector Meson Production:

HERMES Results

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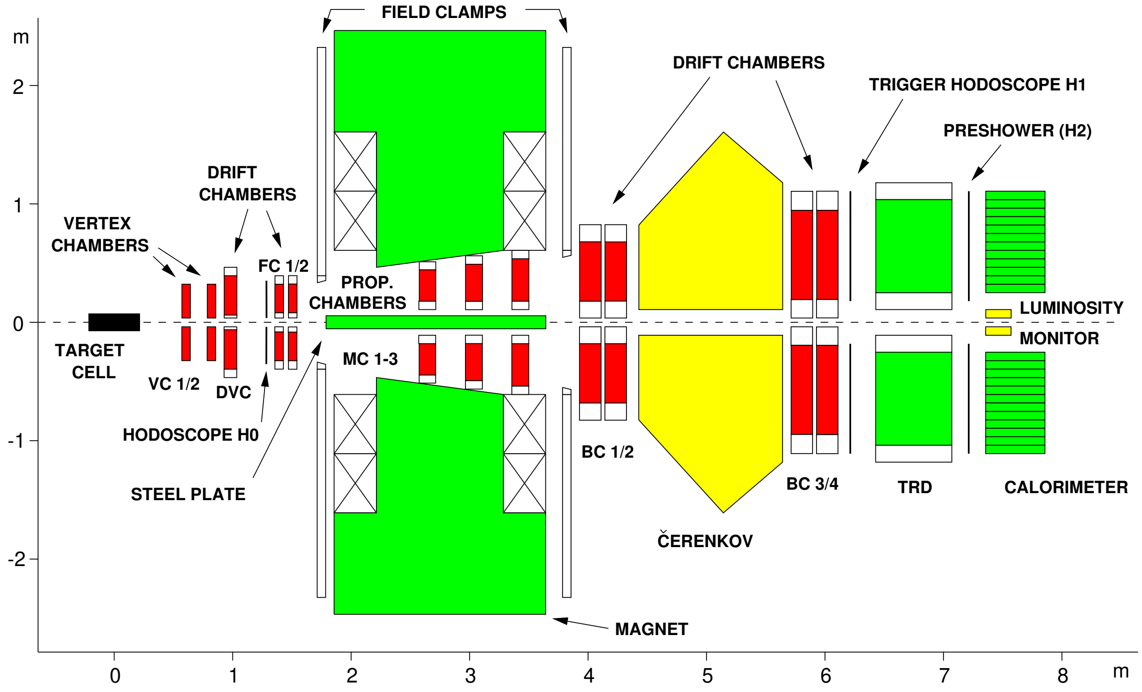
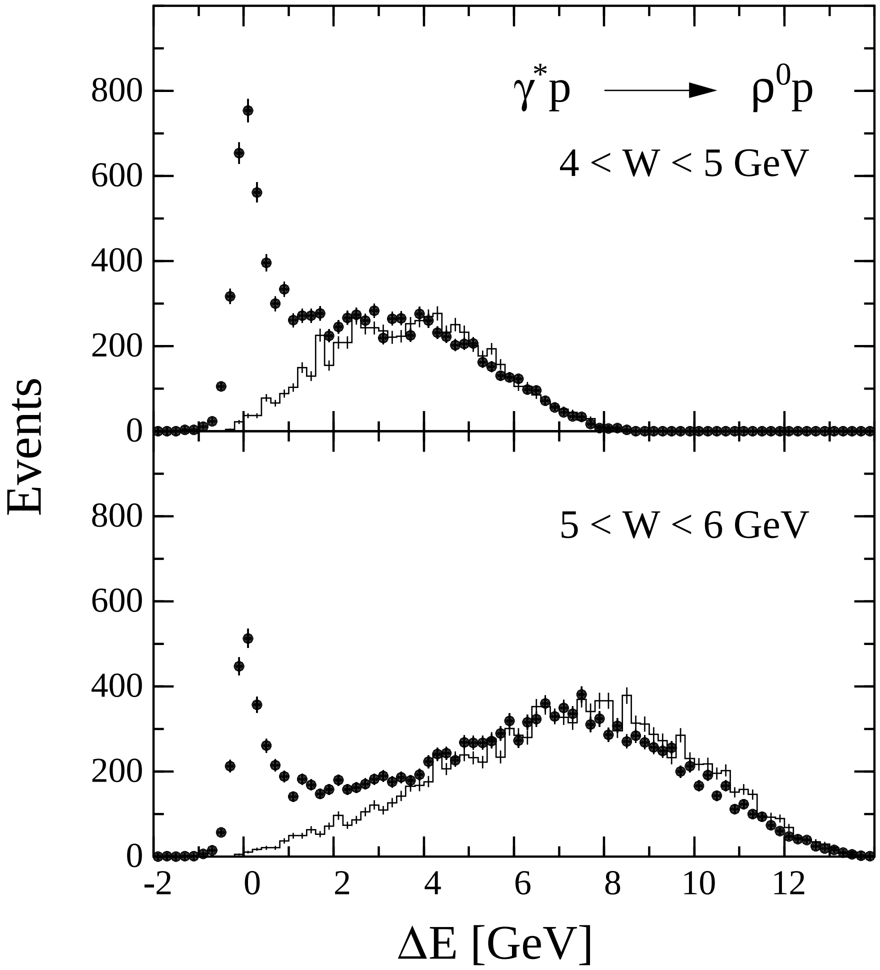
- The Experiment
- ρ^o and ϕ Production:
  - selection of diffractive events
  - cross section, $W-$dependence
  - cross section ratio $\sigma_\phi/\sigma_{\rho^o}$
  - σ_L/σ_T from angular distributions
  - Q^2-dependence
- Summary

The Experiment in 1995-1997



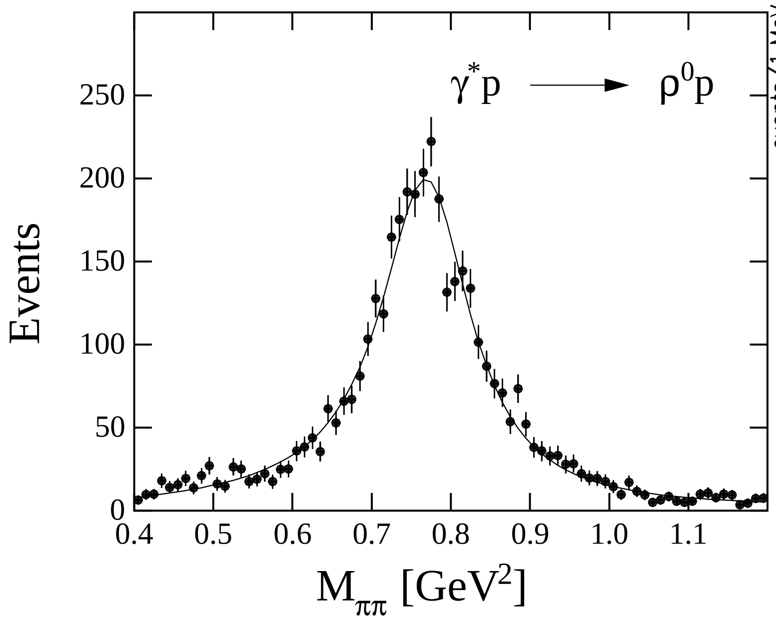
- Two identical halves of forward spectrometer having acceptance $40 < \Theta < 220 mrad$ with momentum resolution $\leq 1\%$.
- Identification of electron with efficiency $> \ 97\%$ at hadron contamination $< 1\%$.
- Cherenkov detector momentum thresholds for pions 4 GeV/c and kaons 13 GeV/c in $'96,' 97$.
- Longitudinally polarised $e^{\pm}$ beam in HERA storage ring ($P = 27.5$ GeV/c, current 40 mA, $P_{beam} = 40 \ldots 60\%$)
- Internal storage cell gas target with high density:
  - polarised: $10^{14 \ldots 15}$ nucl./cm^2, polarization 90% for H/D.
  - unpolarised: $10^{15 \ldots 16}$ nucl./cm^2

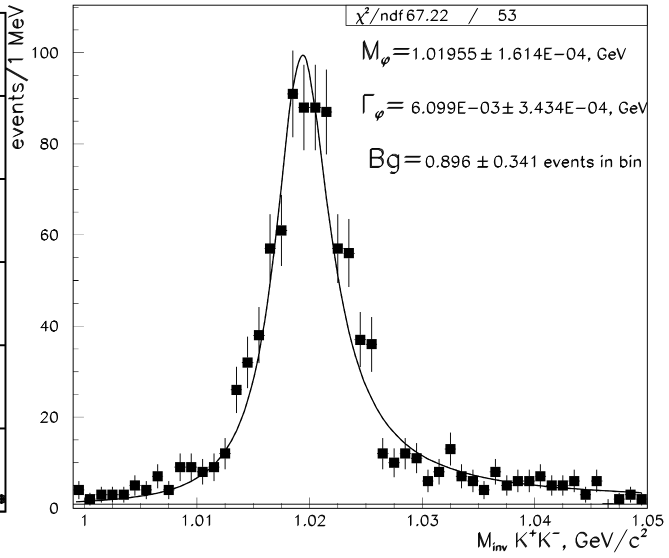
Diffractive ρ^o and ϕ



- Main cuts:
  - ρ^o,ϕ select exclusive: -0.4 GeV$< \Delta E < 0.4$ GeV
  - ρ^o,ϕ select diffractive: -$t' < 0.4 GeV^2$
  - ρ^o select mass: 0.6 GeV$< M_{2\pi} <$1 GeV
  - ρ^o eliminate ϕ background: 1.04 GeV $< M_{2K}$
  - ϕ select mass: 0.99 GeV $< M_{2K} <$1.05 GeV
  - ϕ eliminate background: $\mid p_1 - p_2 \mid \leq 0.3 * (p_1 + p_2)$
  - ϕ kaon PID: $P_{K+} > 4$ and $P_{K-} > 4$ GeV/c
- Kinematics
  - $\nu = 5 \div 23$ GeV
  - $Q^2 = 0.7 \div 5$ GeV
  - $W = 4. \div 6.$ GeV
  - $x_{Bj} = 0.02 \div 0.22$

Mass Peaks





$\rho \to \pi^+\pi^-(100\%)$

$M_{\rho^o} = 776 \pm 3$ MeV

$\Gamma\rho^o = 147 \pm 9$ MeV

$n_s = 2.2 \pm 0.4$

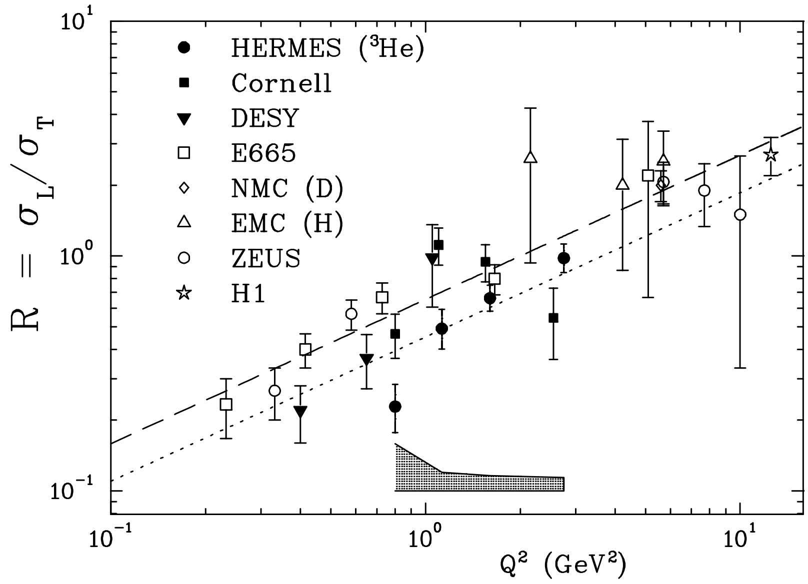
$\phi \to K^+K^-(49\%)$

$M_\phi = 1019.55 \pm 0.16$ MeV

$\Gamma_\phi = 6.099 \pm 0.343$ MeV

Luminosity $\approx 108 pb^{-1}$ at ${}^1H$ target of 1996,1997 data.

Data of $R_{\rho^o} \equiv \sigma_L/\sigma_T$



Measured from the matrix elements consistent with natural parity exchange and SCHC

$R \equiv \sigma_L/\sigma_T = \frac{1}{\epsilon}\frac{r^{04}_{00}}{1-r^{04}_{00}}$

Fit of Q^2-dependence:

$$R(Q^2) = c_0(W) \cdot \left[\frac{Q^2}{M^2_\rho}\right]^{c_1} \quad (1)$$

VDM predicts $c_0 = const(W)$ and $c1 = 1$.
Two values of c_0:
$2 < W < 7$ GeV (DESY and HERMES) dashed line
$7 < W < 140$ GeV (EMC, NMC, E665, Zeus, and H1) dotted line:

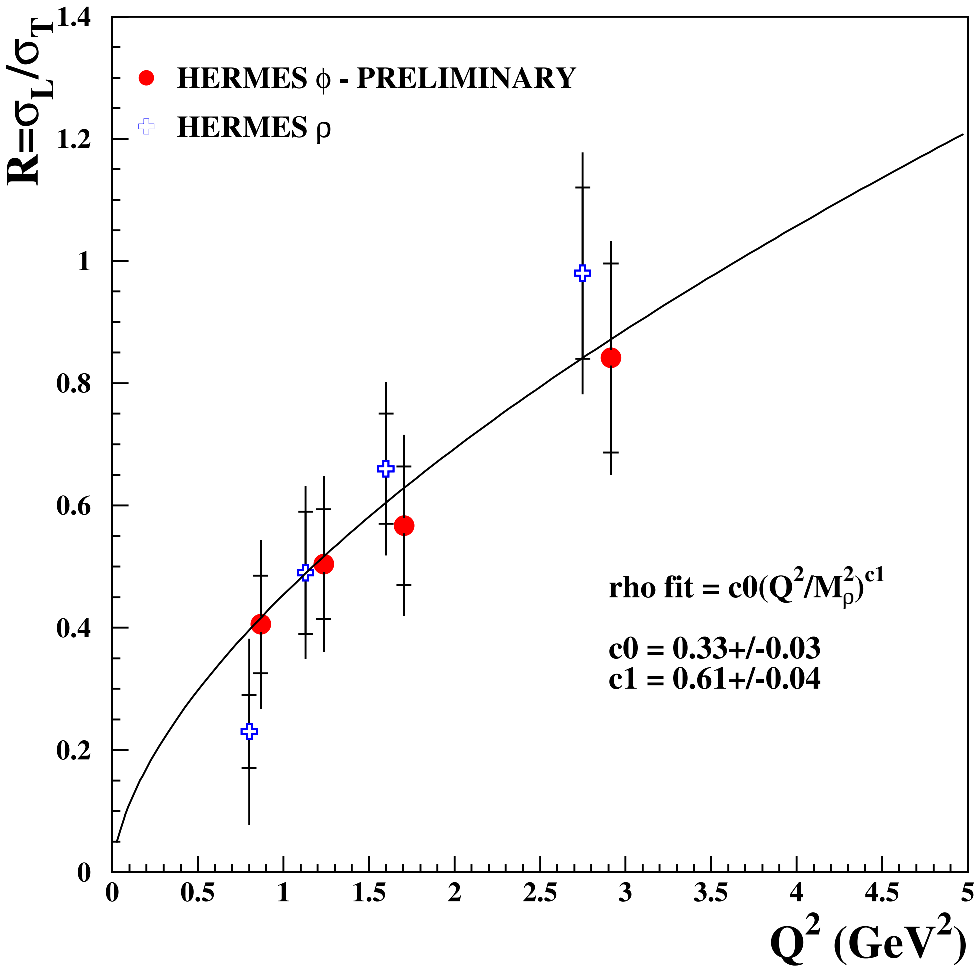
$$c_0 = \begin{cases} 0.33 \pm 0.03 & (\, 4 < \langle W \rangle > 7 \text{ GeV}) \\ 0.48 \pm 0.03 & (\langle W \rangle > 7 \text{ GeV}) \end{cases}$$

$$c_1 = 0.61 \pm 0.04.$$

Q^2–dependence of R is in disagreement with the VDM prediction, consistent with previous experiments, and suggest enhanced transverse strength at lower energy for fixed Q^2.

HERMES collab, DESY 99-199, hep-ex/0002016

$R_\phi(Q^2)$ vs $R_{\rho^o}(Q^2)$ at

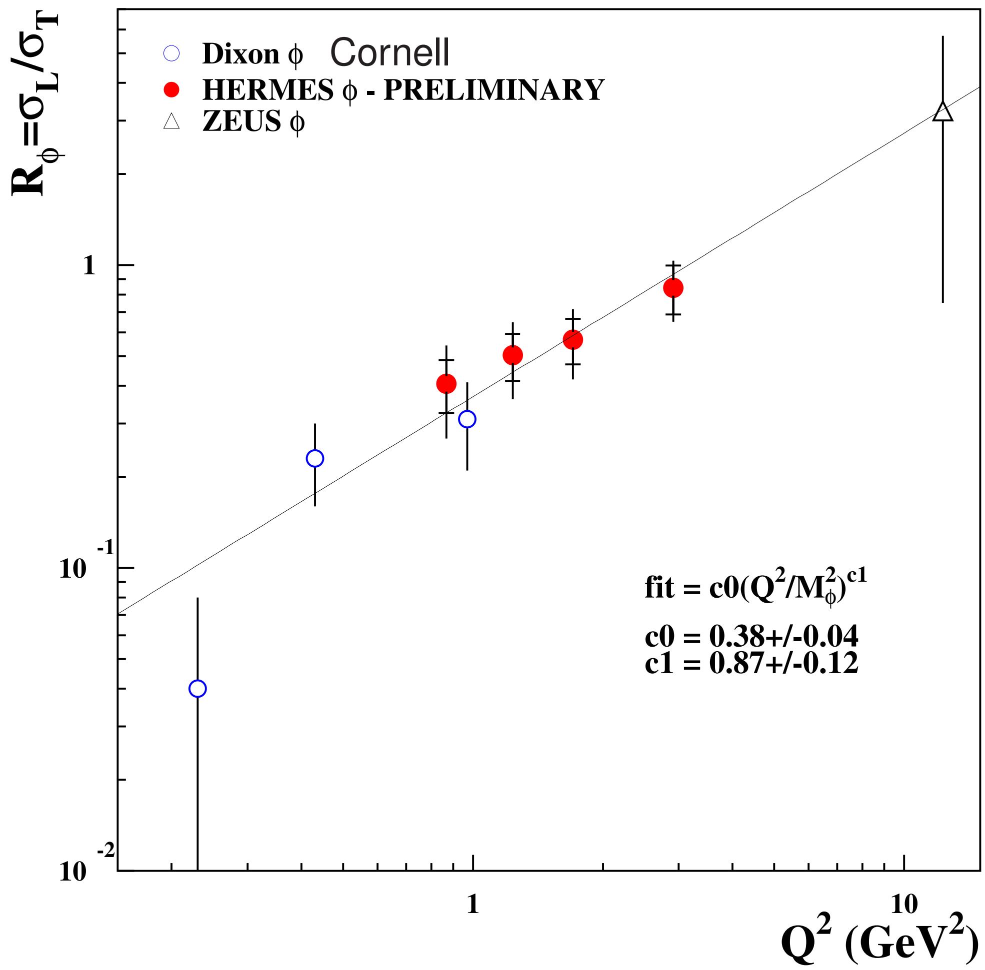


→ $R_\phi(Q^2) = R_{\rho^o}(Q^2)$ at $W \sim 5$ GeV

→ No enhanced transverse strength for ϕ.

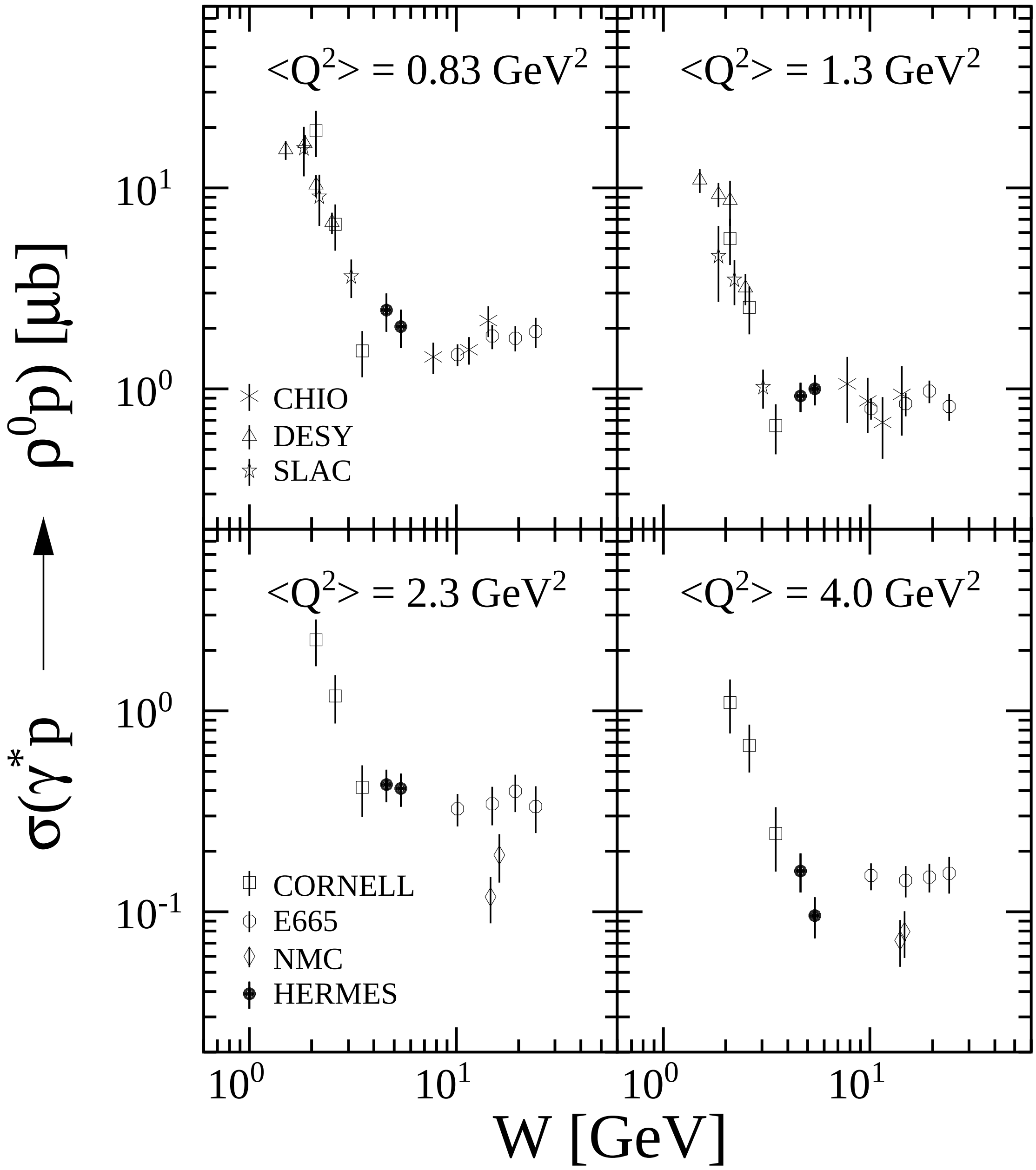
FIT of $R_\phi \equiv \sigma_L/\sigma_T$

Comparison with existing data



$\rightarrow c1_\phi$ is consistent with VDM.

ρ^o Cross Section (Q^2, W)



The error bars represent both the statistical and systematic uncertainties added in quadrature.

$\rightarrow$ HERMES data are in the transition region where different production mechanisms involved.

HERMES collab. DESY 00-058.

ρ^o Cross Section (Q^2, W)

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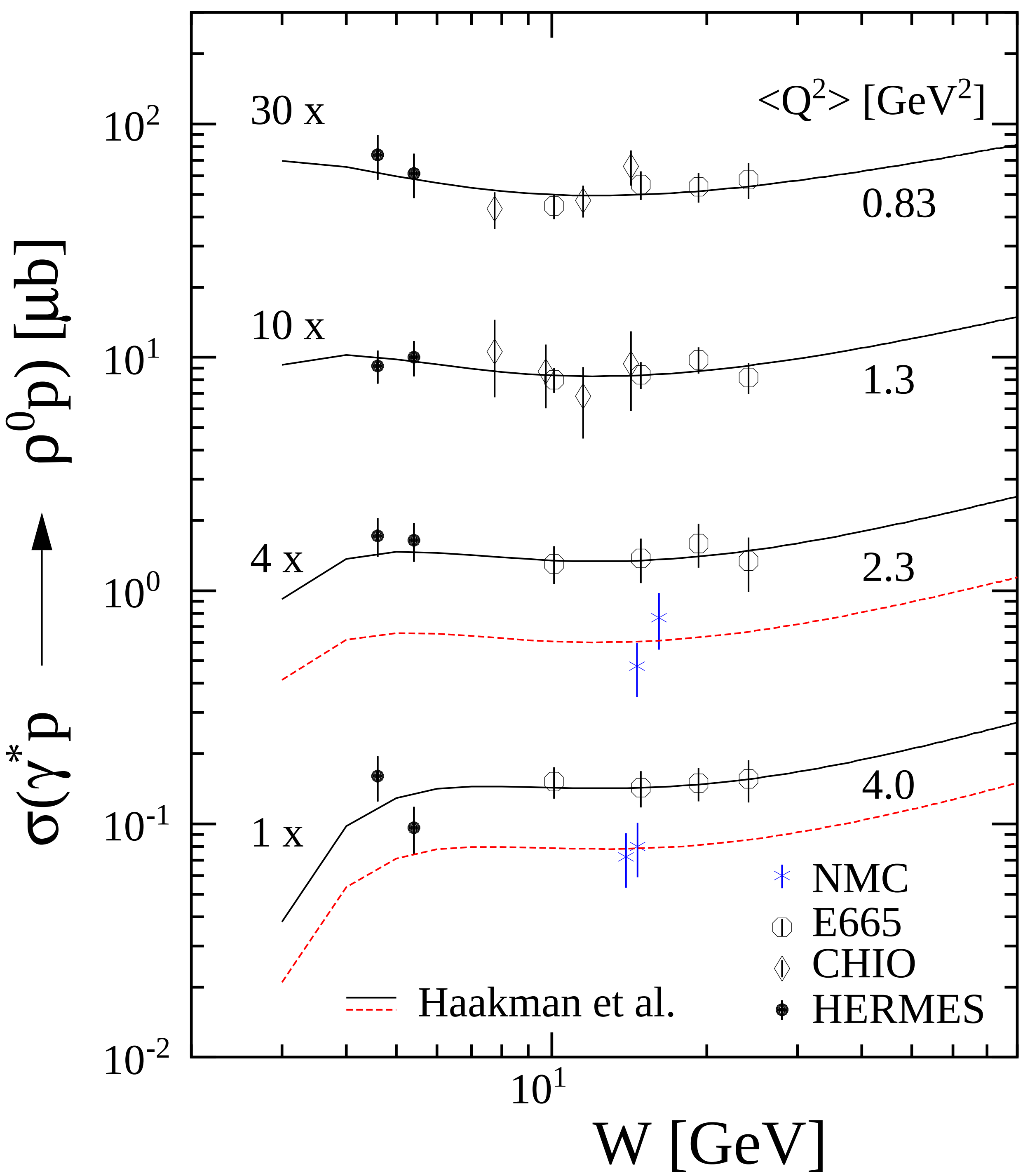
Comparison with Reggeon based calculations

of L.P.A.Haakman, A.Kaidalov, J.H.Koch, Phys.Lett.B **365** (1996) 411.



The relation between the ρ^0 production cross section and the structure function is in the expression for the t-dependence of the cross section

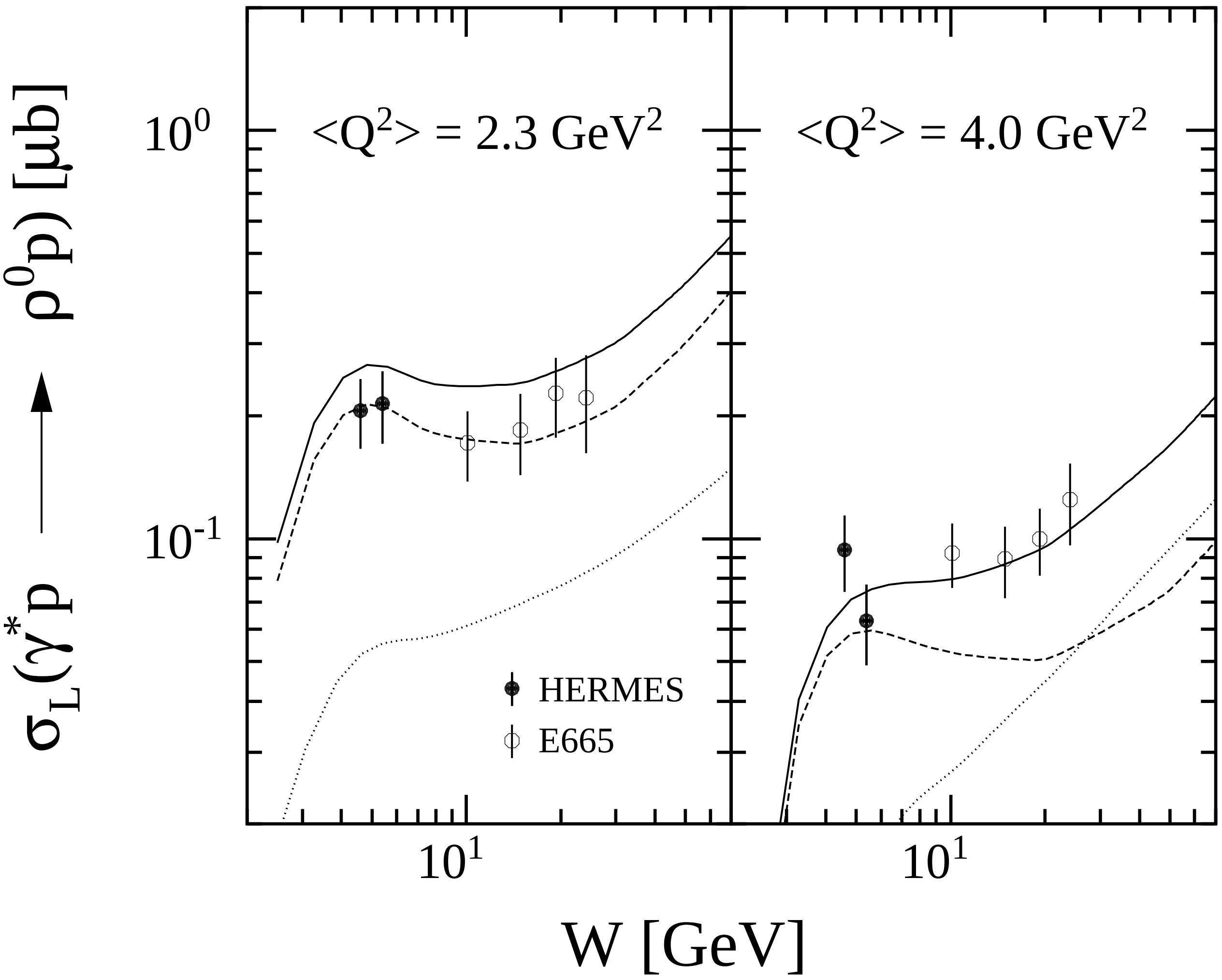
$\frac{d\sigma}{dt} = f_\rho(Q^2) F_2^{\mathrm{p}}(x, Q^2)^2 \exp[\Lambda(W)t]$.(2)

$f_\rho(Q^2)$ has been obtained from a fit to the experimental data.

ρ^o Longitudinal Cross Section

Comparison with recent OFPD calculations

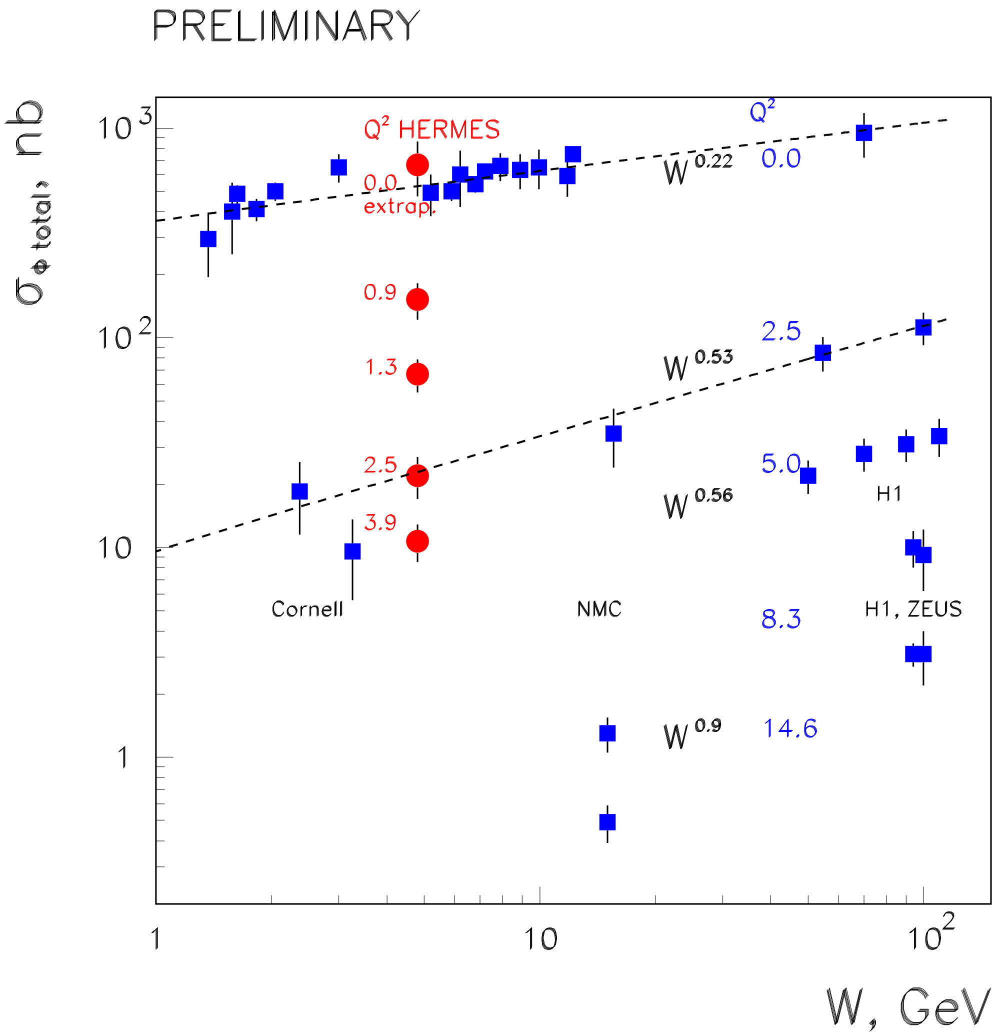
M.Vanderhaeghen, P.A.M. Guichon, M. Guidal, Phys.Rev.Lett. **80** (1998) 5064.



Dotted curve - 2-gluon exchange, dashed - quark exchange, solid - sum.

$\rightarrow$ Domination of quark exchange at $W \sim 5$ GeV.

ϕ Cross Section (Q^2, W)

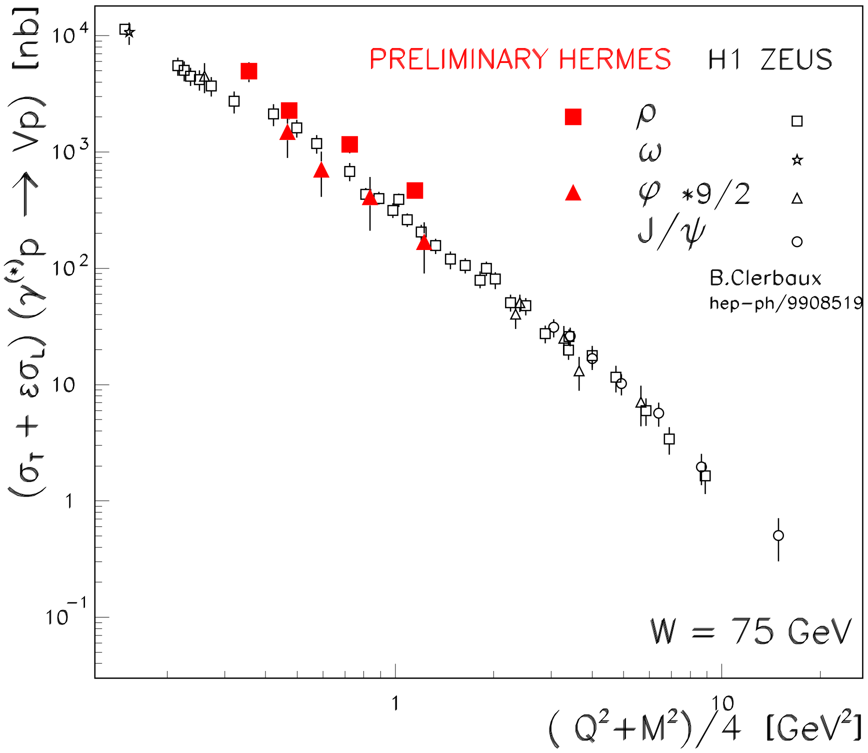


$\rightarrow Q^2-$dependence of $W^{\delta_\phi(Q^2)}$ exponent:

Q^2, GeV^2	$\delta_\phi(Q^2)$
0.0	0.22
2.5	0.53 ± 0.09
5.0	0.56 ± 0.25
$>$8.0	0.90 ± 0.18

S.Kananov, DIS ’98 Proceedings, 308, 1998.

$\sigma_{\rho^o,\phi}$ scaled up to $W = 75$ GeV



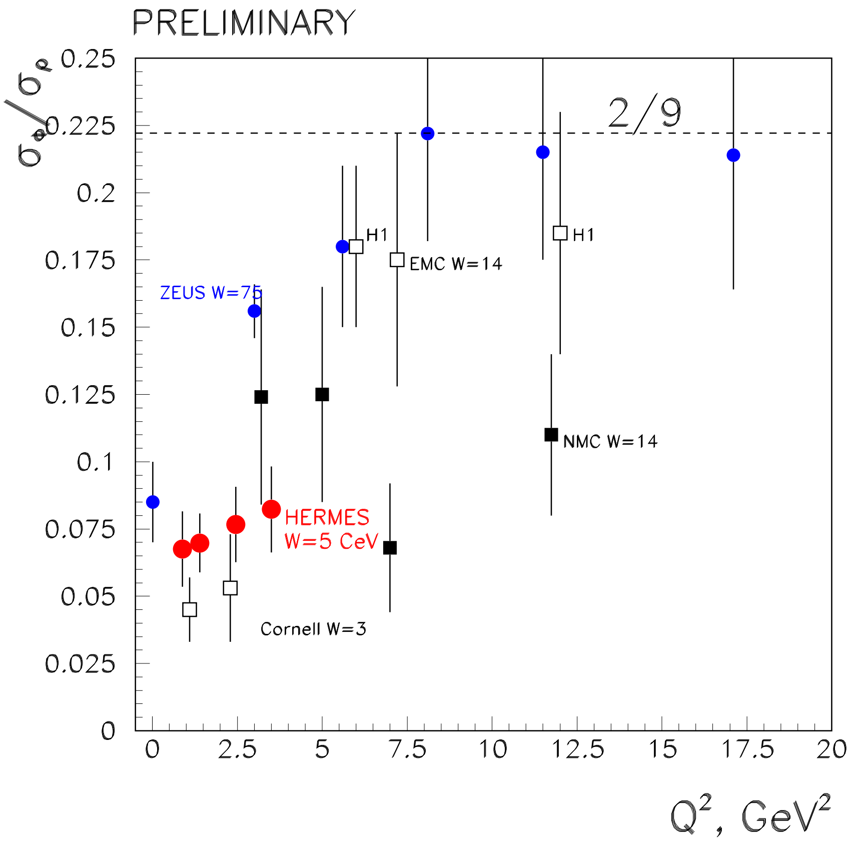
Use $W^{\delta_{\rho^o}(Q^2)}$ dependence from H1 and ZEUS data for HERMES $(\sigma_L + \sigma_T)$ of ρ^o and ϕ cross sections by means of the linear fit of the points at $\delta(0) = 0.22$ and $\delta(3.5) = 0.4$

H.Abramowicz,A.Caldwell DESY 98-192, H.Abramowicz DESY 00-025,hep-ph/0001054

$\rightarrow$ ρ^o at HERMES - additional to 'IPomeron exchage' mechanism involved

$\rightarrow$ ϕ at HERMES - consistent with 'IPomeron exchage', but can not distinguish $\delta_{\rho^o}(Q^2)$ and $\delta_\phi(Q^2)$ dependences at present statistics.

Ratio of $\sigma_\phi/\sigma_{\rho^o}$



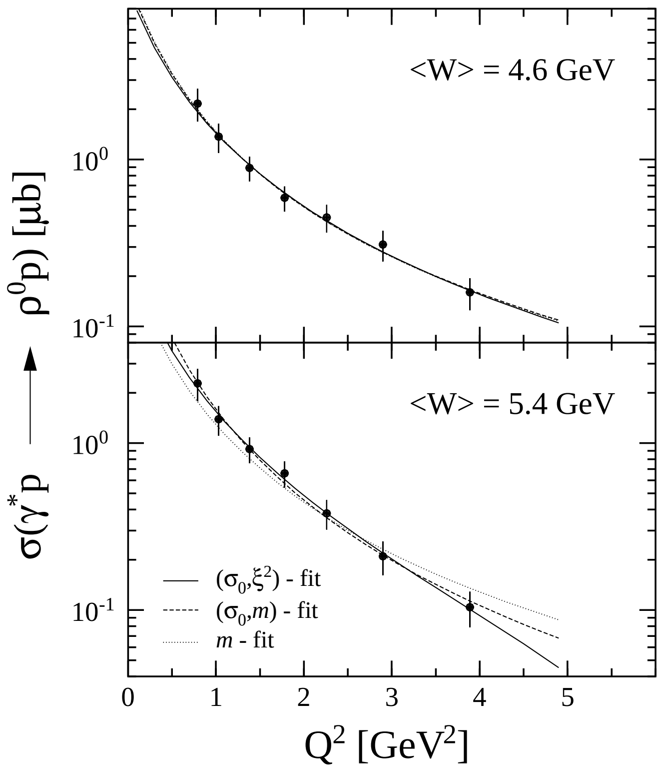
$\rightarrow$ $W-$dependence of the ratio $\sigma_\phi/\sigma_{\rho^o}$ at $Q^2 = 2.5 \sim 4$ GeV^2.

Cornell[1] at $W \sim 3$ GeV
HERMES at $< W >= 5$ GeV
NMC[2] at $W \sim 14$ GeV
ZEUS[3] data at $< W >\sim 75$ GeV

Systematic errors partially cansel out for the ratio at the same data sample.

[1] D.G. Cassel et al, Phys.Rev.D, V.24,11,1981,2787-282
[2] NMC Collab., M.Arneodo et al, Nucl.Phys. B429 (1994) 503-529
[3] ZEUS Collab. M. Derrick et al, Preprints DESY 96-002, 96-067, 1996

Fits of Q^2 dependence



Solid line fit $$\sigma(Q^2) = \sigma(Q^2=0) \cdot \left(\frac{m_\rho^2}{Q^2+m_\rho^2}\right)^2 \cdot (1+\epsilon\cdot\xi^2 Q^2/m_\rho^2)$$

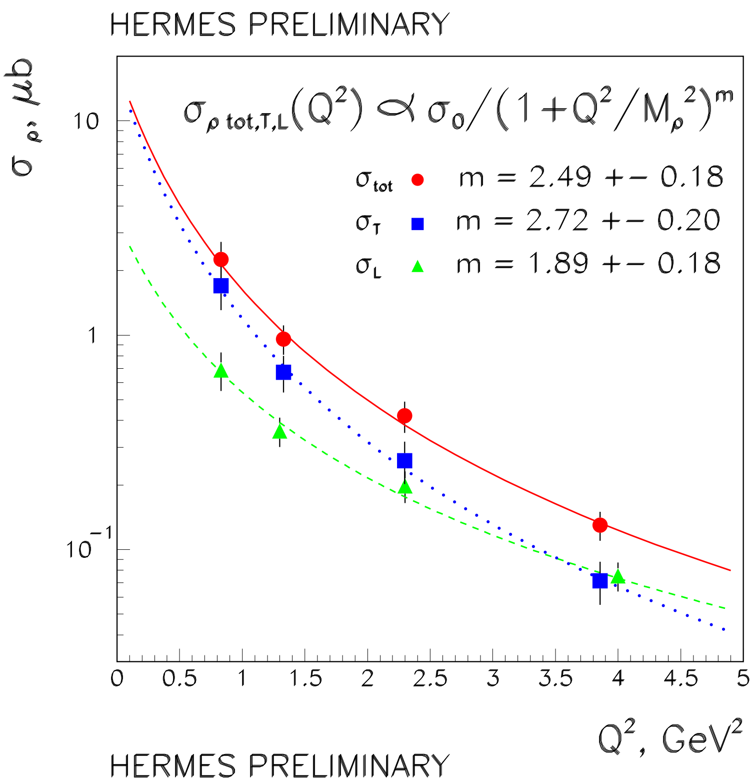
Dashed line fit $$\sigma(Q^2) = \sigma(Q^2=0) \cdot \left(\frac{m_\rho^2}{Q^2+m_\rho^2}\right)^m \cdot (1+\epsilon R_{data}(Q^2))$$

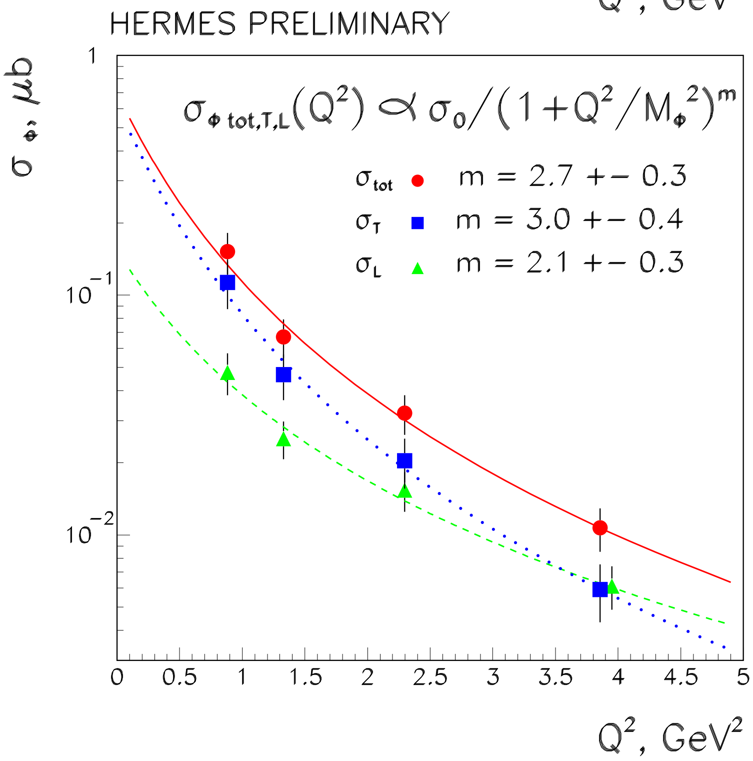
ρ^o fits	$\langle W \rangle$ = 4.6 GeV	$\langle W \rangle$ = 5.4 GeV	$\langle W \rangle \sim 15$ GeV E665
σ_0 [μb] ξ^2	10.7 $\pm$ 1.8 -0.023 $\pm$ 0.049	13.1 $\pm$ 1.7 -0.13 $\pm$ 0.03	10.30 ± 0.33 -0.04 $\pm$ 0.02
σ_0 [μb] m	11.2 $\pm$ 2.9 2.42 $\pm$ 0.18	19.7 $\pm$ 4.9 2.83 $\pm$ 0.18	10.23 ± 0.56 2.51 $\pm$ 0.07
ϕ fits	$\langle W \rangle$ = 5.0 GeV		
σ_0 [μb] ξ^2	0.477 $\pm$ 0.08 -0.168 $\pm$ 0.050		
σ_0 [μb] m	0.667 $\pm$ 0.196 2.96 $\pm$ 0.27		

$\rightarrow m_{\rho^o}$ consistent with E665

$\rightarrow m_\phi$ is larger then m_{ρ^o}

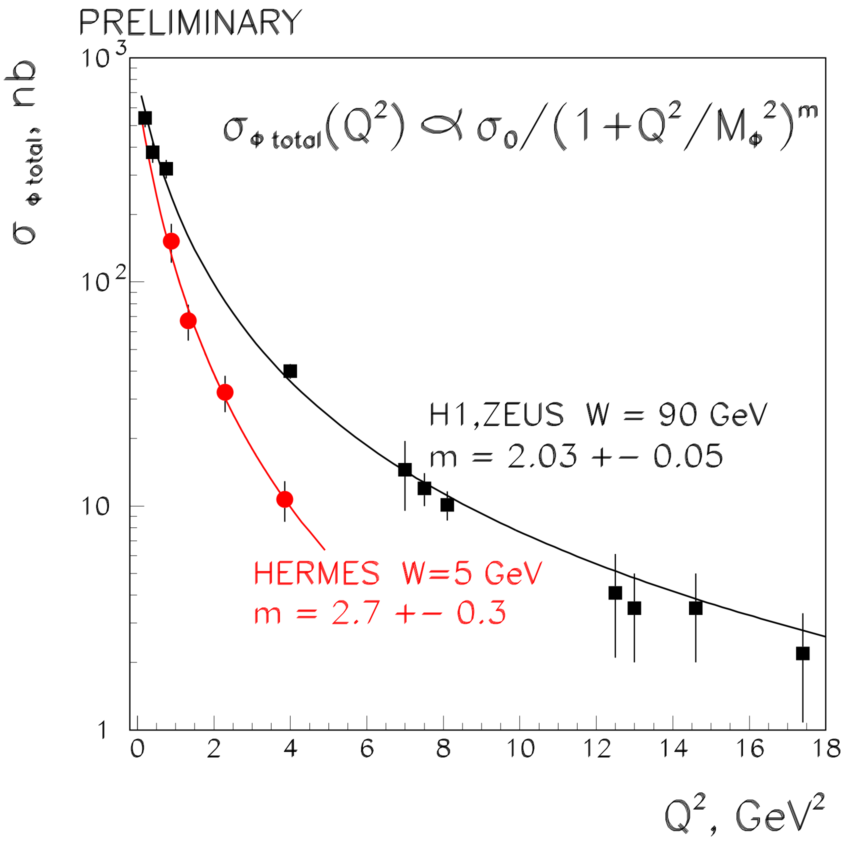
ρ^o ϕ Fit of $\sigma_{total,T,L}(Q^2)$





$\rightarrow$ m_ϕ is larger then m_{ρ^o}
$\rightarrow$ m_T is larger then m_L for ρ^o and ϕ

ρ^o ϕ **Fit of** $\sigma_{total,T,L}(Q^2)$



which σ	m at HERMES	m at H1, ZEUS
$\sigma_{total\phi}$	2.70 $\pm$ 0.28	2.03 $\pm$0.05 [1]
$\sigma_{L\phi}$	2.067 $\pm$ 0.275	
$\sigma_{T\phi}$	3.018 $\pm$ 0.344	2.8 $\pm$0.1 [2]
$\sigma_{total\rho}$	2.49 $\pm$ 0.18	2.37$\pm$0.10 [2]
$\sigma_{L\rho}$	1.89 $\pm$ 0.18	
$\sigma_{T\rho}$	2.72 $\pm$ 0.23	2.47$\pm$0.03 [2]

[1] S.Kananov, DIS '98 Proceedings, 308, 1998.

[2] B.Clerbaux, hep-ph/9908519.

$\rightarrow m_\phi$ at $W \sim 5$ GeV is larger then at $W \sim 75$ GeV

SUMMARY

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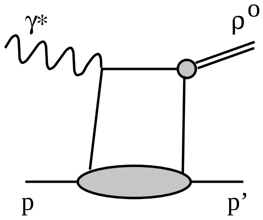
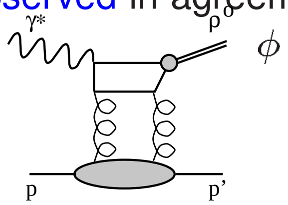
- ρ^o cross section
  - domination of 'quark exchange' mechanism at $W \sim 5$ GeV occurs



(Reggeon based calculations, OFPD calculations for σ_L, small R_{ρ^o}, $\sigma_\phi/\sigma_{\rho^o}$)

- ϕ cross section
  - new HERMES data in agreement with previous
  - $W^{\delta(Q^2)}-$dependence observed in agreement with 'IPomeron exchange' predictions



- ϕ over ρ^o cross section ratio presents clear $W-$dependence at $Q^2 = 2.5 \sim 4$ Gev^2 where no independent quark generation occurs
- $R = \sigma_L/\sigma_T$ from angular distributions
  - enhanced σ_T for ρ^o at $W < 7$ GeV
  - $R_\phi(Q^2) = R_{\rho^o}(Q^2)$ at HERMES
- the same $R_\phi(Q^2)$ over all world data
- Q^2- dependence
  - ρ^o slope is more consistent with E665,H1 and ZEUS data ...even at different production mechanisms
  - ϕ slope is significantly steeper then at H1 and ZEUS data. For the total and transverse cross sections it reaches the pQCD expected value of 3.
- $\sigma_T(Q^2)$ dependence is significantly steeper then $\sigma_L(Q^2)$ for ρ^o and ϕ .