On two-photon production of two ρ^0-mesons

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in collaboration with

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and thanks to

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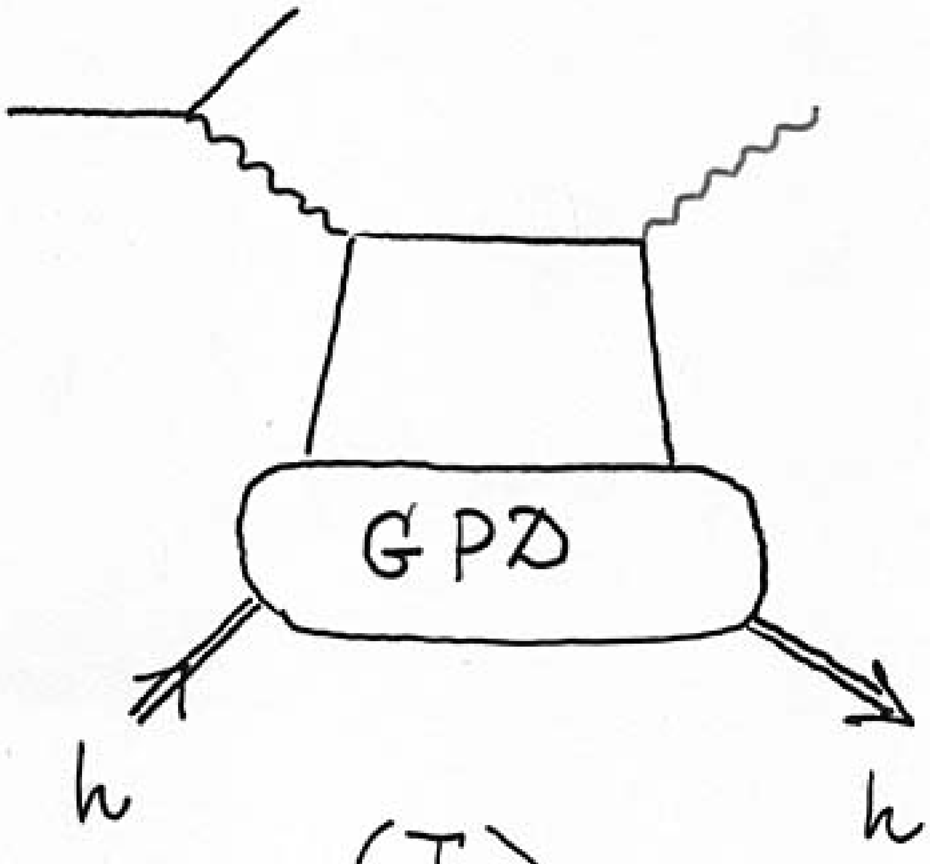
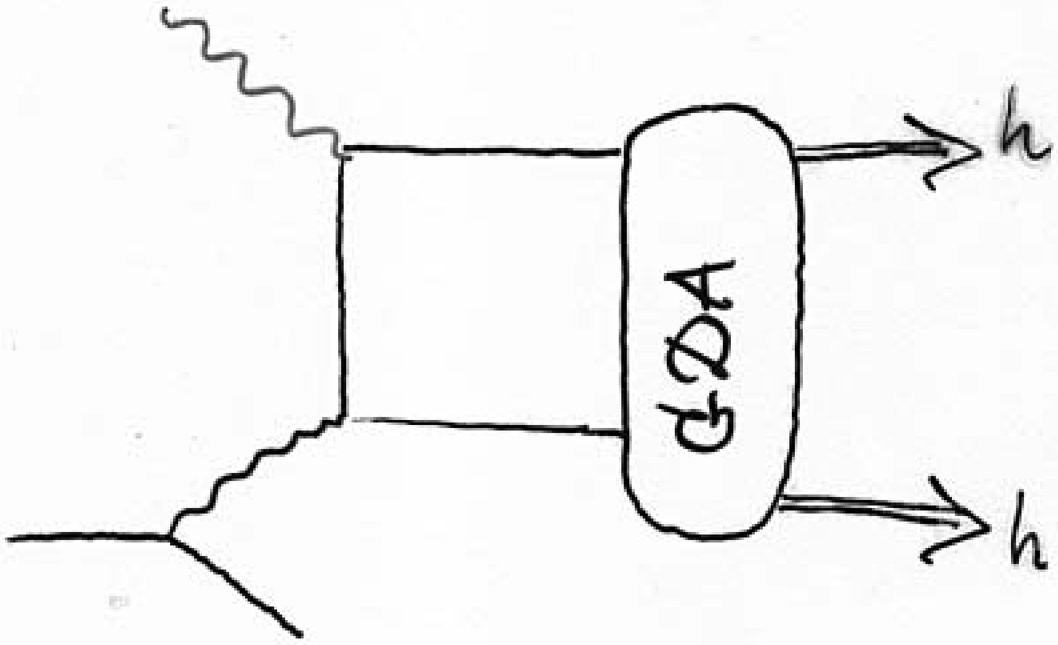
The new kinds of partonic distributions (GPD) and distribution amplitudes (GDA) are arisen from



(I)



(II)

Here, $h = \{N, \pi, \rho, \ldots\}$; $\sim\sim \Rightarrow Q^2 \to \infty$; $\sim\sim \Rightarrow q'^2 \to 0$

I) • $h = N \Rightarrow$ a good subject from experimental point of view, the theoretical investigations are related to more complicated calculations, than for meson case, due to spin ½

• $h = \pi, \rho, \ldots \Rightarrow$ the theoretical part is attracted thanks to relative simplicity. But the problems of experimental character certainly exist owing to the absence of π-target.

II) The probing the meson structure is available from both exper and theor. points of view.

• exp. $\gamma\gamma^* \to \pi\pi$ CLEO Coll., J. Gronberg et al., PR D 57, 33 (1998)

• theor. $\gamma\gamma^* \to \pi\pi$ twist-2 and twist-3 have been considered in

M. Diehl et al., PRL 81, 1782 (1998)

N. Kivel & L. Mankiewicz, PR D 63, 054017

I.V.A and O.V. Teryaev, PLB 509, 95 (2001)

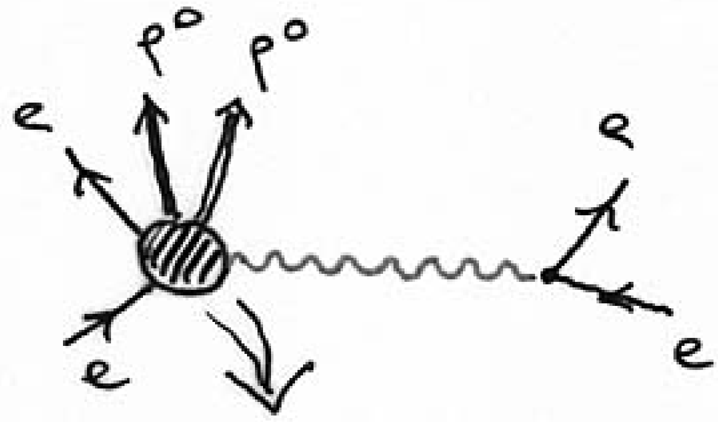
New (prelim.) experimental data have been obtained by L3 Collab. at LEP for $e^+e^- \to e^+e^- \rho^0\rho^0$ process (to be published in Phys. Lett. B / the talk of S. Nesterov

We focus on Q^2-dependence of $d\sigma_{ee}/dQ^2$

- exp.: $$\frac{d\sigma_{ee}}{dQ^2} \sim \frac{1}{Q^6}$$

- theory:

$$\frac{d\sigma_{ee}}{dQ^2} \sim \Big| \quad \Big|^2$$

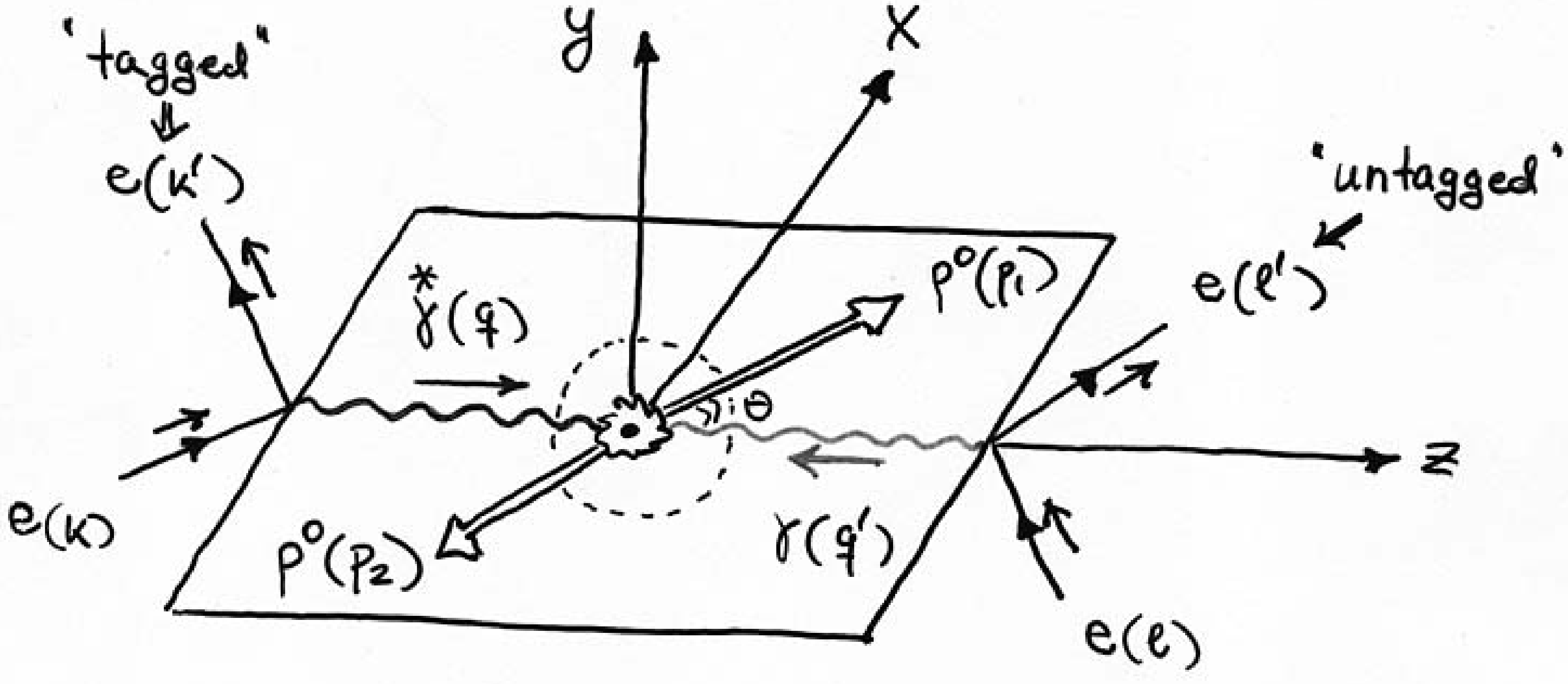


$$\underbrace{\left| \sim\sim\sim \right|^2}_{(1/Q^2)^2} \times \underbrace{d^3PS}_{1/Q^2} \times \underbrace{\left|T(\gamma\gamma^* \to 2\rho^0)\right|^2}_{Q^0\ (\text{tw-2})}$$

if there are no Q^2 depend. in H-structures

Possible treatment: the data probe the partonic picture of the composite structure of hadrons — scaling

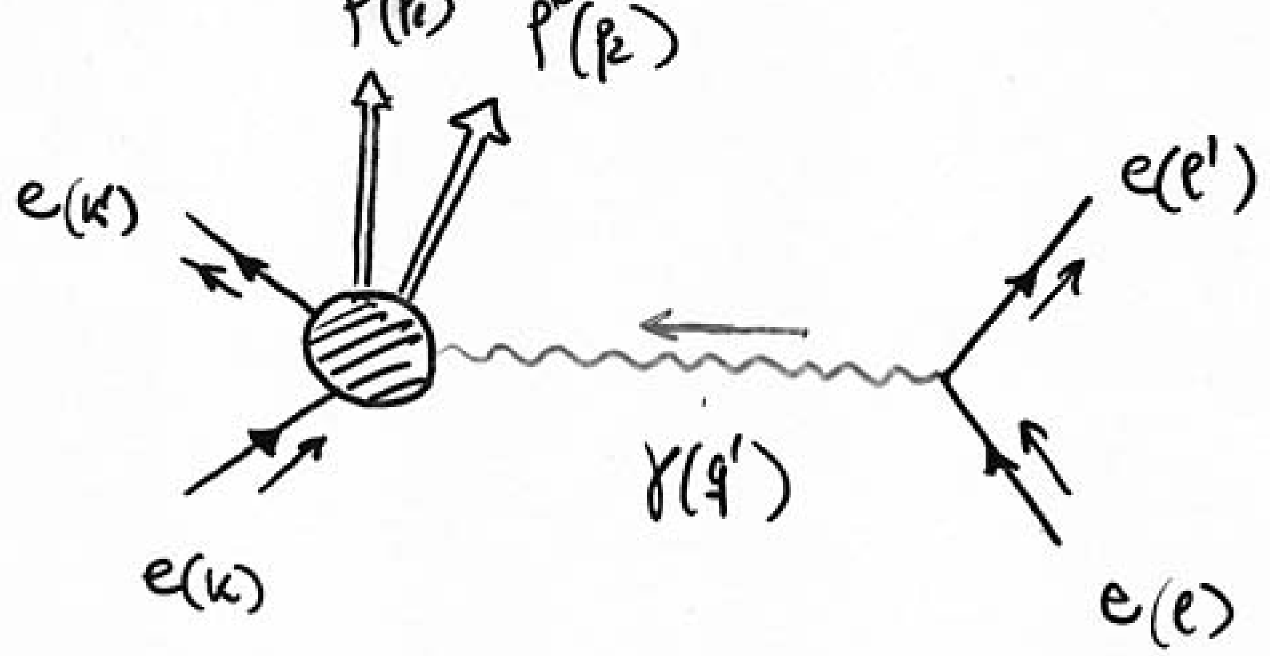
The reaction which we study is



$$\underline{e(k) + e(l) \rightarrow e(k') + e(l') + \rho^0(p_1) + \rho^0(p_2)}$$

nd the sub-process of this reaction is

$$\underline{e(k) + \gamma(q') \longrightarrow e(k') + \rho^0(p_1) + \rho^0(p_2)}$$



where

$q^2 = -Q^2$ is <u>very large</u>

$q'^2 \approx 0$

Within the $\gamma\gamma^*$ center of mass frame we write

$$q = (q_0, \vec{0}_T, q), \quad p_1 = (p_1^0, |\vec{p}_1|\sin\theta, 0, |\vec{p}_1|\cos\theta)$$

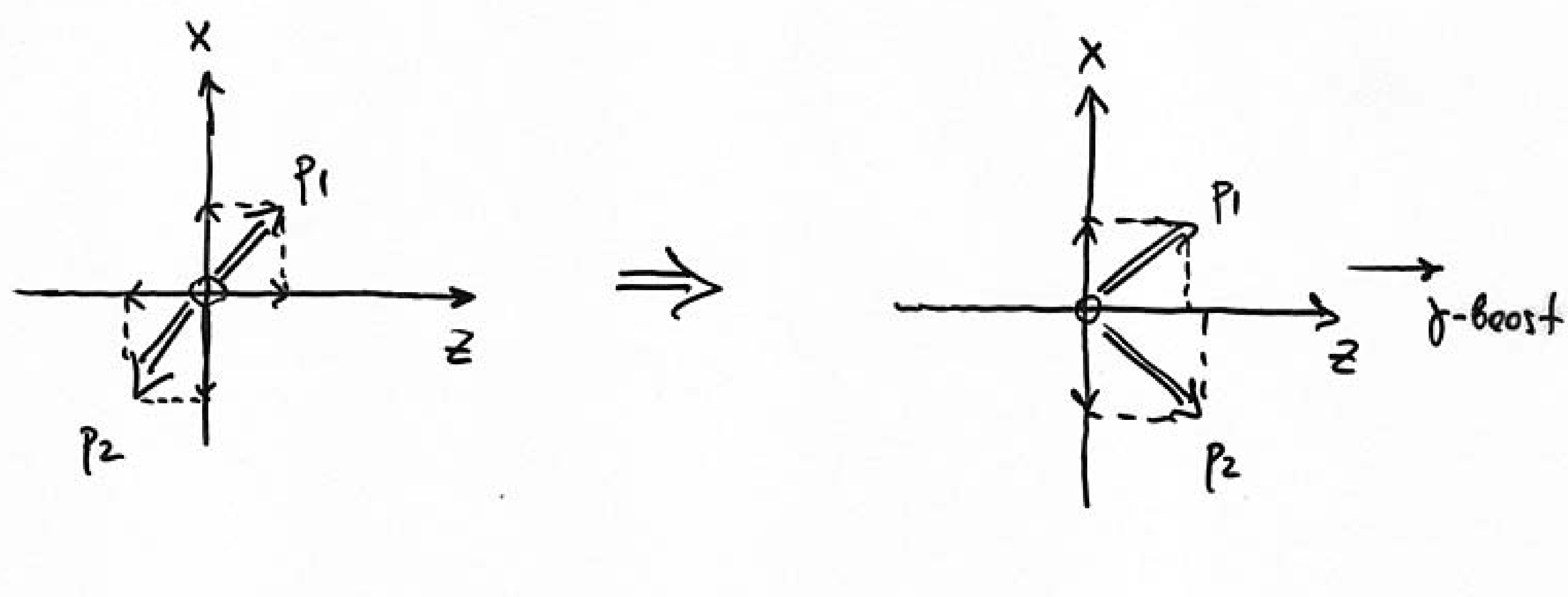
nd $k_0 = E_1$, $l_0 = E_2$ for the initial lepton energies;

he Mandelstam variables are written as

$$S_{ee} = (k+l)^2 \approx 2kl, \quad S_{e\gamma} = (k+q')^2 \approx 2kq' = x_2 S_{ee}$$

here the fraction x_2 defined as $q_0' = x_2 l_0$ is introduced.

c.m.s. $\qquad\qquad\qquad\qquad$ boosted c.m.s.



Basis of light-cone vectors

$$p^2 = n^2 = 0 \,, \quad n^+ = p^- = 0 \,, \quad pn = 1$$

$$\dim_M [p] = +1 \quad , \quad \dim_M [n] = -1$$

With the help of this basis, the meson momenta are presented as

$$p_1^\mu = \frac{1+\zeta}{2} p^\mu + \frac{1-\zeta}{2} \frac{W^2}{2} n^\mu - \Delta_T^\mu$$

$$p_2^\mu = \frac{1-\zeta}{2} p^\mu + \frac{1+\zeta}{2} \frac{W^2}{2} n^\mu + \Delta_T^\mu$$

As usually for the DA kinematics, we introduce

$$\Delta^\mu = p_2^\mu - p_1^\mu \quad , \quad P^\mu = p_2^\mu + p_1^\mu$$

the skewedness parameter ζ is defined by

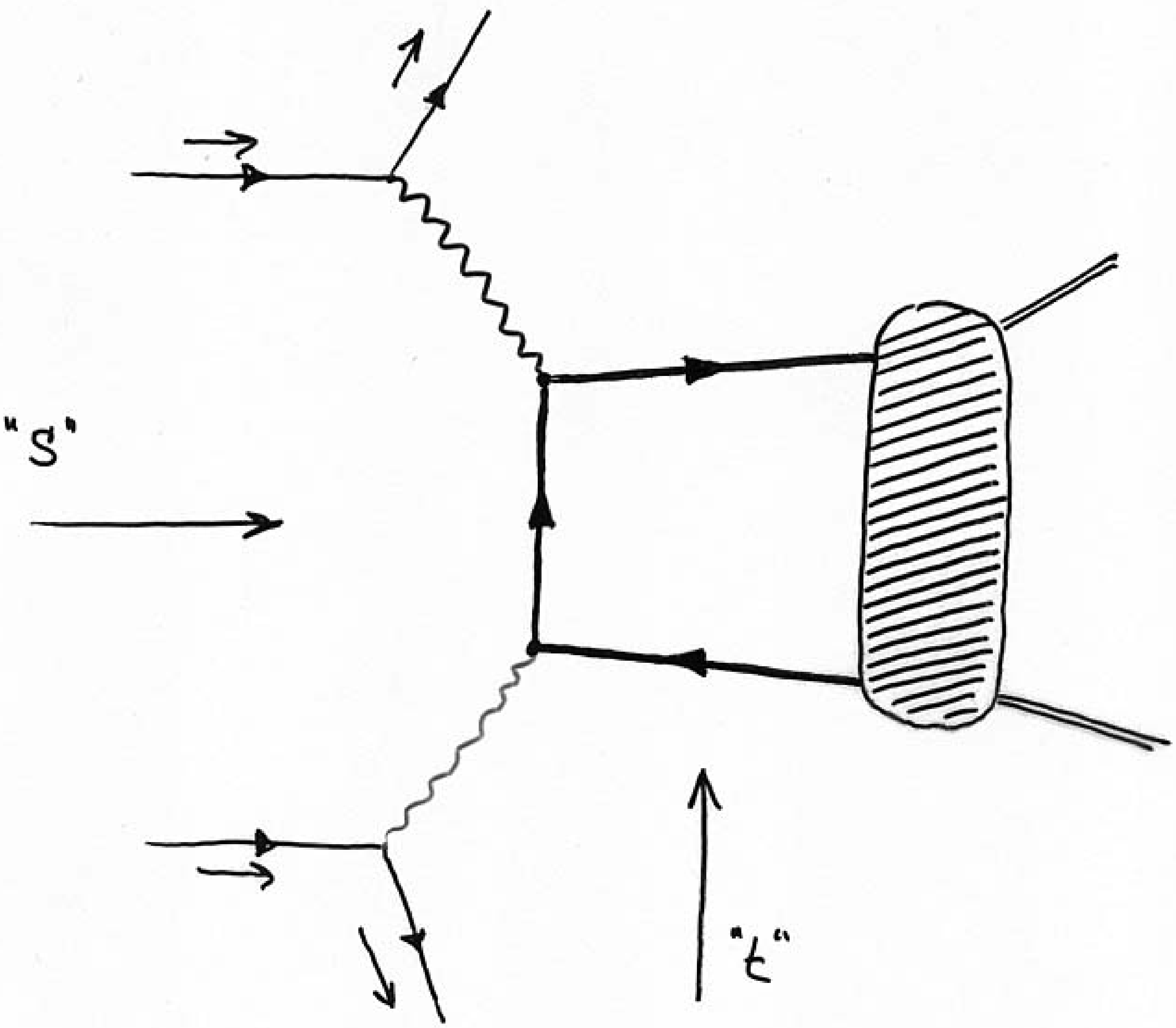
$$\Delta n = - \zeta P n$$

or

$$\frac{1+\zeta}{2} = \frac{p_1^+}{P^+} = \frac{1+\beta\cos\theta}{2} \quad , \quad \beta = \sqrt{1 - \frac{4m^2}{W^2}}$$

Note also that the transfer momentum $\Delta^T = (0, \vec{\Delta}_T, 0)$ is given by

$$\Delta_T^2 = - \vec{\Delta}_T^2 = t + (W^2 - 4m^2) \cos^2\theta$$



Leading twist (twist-2) accuracy

Parameterization of relevant matrix elements

Keeping the terms of leading twist-2 contributions, the vector and axial correlators can be written as:

$$\langle p_1,\lambda_1; p_2,\lambda_2 | \bar{\Psi}(0)\gamma_\mu \Psi(\lambda n) | 0 \rangle = \int_0^1 dy \, e^{-iy\lambda}$$

$$P_\mu \sum_i e_1^\alpha e_2^\beta V_{\alpha\beta}^{(i)}(p_1,p_2,n) H_i^{pp,V}(y,\zeta,W^2)$$

$$\langle p_1,\lambda_1; p_2,\lambda_2 | \bar{\Psi}(0)\gamma_5\gamma_\mu \Psi(\lambda n) | 0 \rangle = \int_0^1 dy \, e^{-iy\lambda}$$

$$P_\mu \sum_i e_1^\alpha e_2^\beta A_{\alpha\beta}^{(i)}(p_1,p_2,n) H_i^{pp,A}(y,\zeta,W^2)$$

Due to parity invariance

$V_{\alpha\beta}^{(i)} \longrightarrow$ 5 tensor structures

$A_{\alpha\beta}^{(i)} \longrightarrow$ 4 tensor structures

$$\bullet \sum_i e_1^\alpha e_2^\beta V^{(i)}_{\alpha\beta}(p_1,p_2,n) H_i^{\rho\rho,V}(y) =$$

$$= -(e_1.e_2) H_1^{\rho\rho,V}(y) + \frac{(e_1.n)(e_2.P)+(e_1.P)(e_2.n)}{P.n} H_2^{\rho\rho,V}(y) -$$

$$- \frac{(e_1.P)(e_2.P)}{2m^2} H_3^{\rho\rho,V}(y) + \frac{(e_1.n)(e_2.P)-(e_1.P)(e_2.n)}{P.n} H_4^{\rho\rho,V}(y) +$$

$$+ \left\{ 4m^2 \frac{(e_1.n)(e_2.n)}{(P.n)^2} + \frac{1}{3}(e_1.e_2) \right\} H_5^{\rho\rho,V}(y)$$

for the vector tensor structures, and

$$\bullet \sum_i e_1^\alpha e_2^\beta A^{(i)}_{\alpha\beta}(p_1,p_2,n) H_i^{\rho\rho,A}(y) =$$

$$i \frac{\epsilon^T_{\alpha\beta} e_1^\alpha e_2^\beta}{(P.n)} H_1^{\rho\rho,A}(y) + i \frac{\epsilon^T_{\alpha\beta}\Delta_\alpha}{P.n} \frac{e_1^\beta(e_2.P)+e_2^\beta(e_1.P)}{m^2} H_2^{\rho\rho,A}(y)$$

$$+ i \frac{\epsilon^T_{\alpha\beta}\Delta_\alpha}{P.n} \frac{e_1^\beta(e_2.P)-e_2^\beta(e_1.P)}{m^2} H_3^{\rho\rho,A}(y) +$$

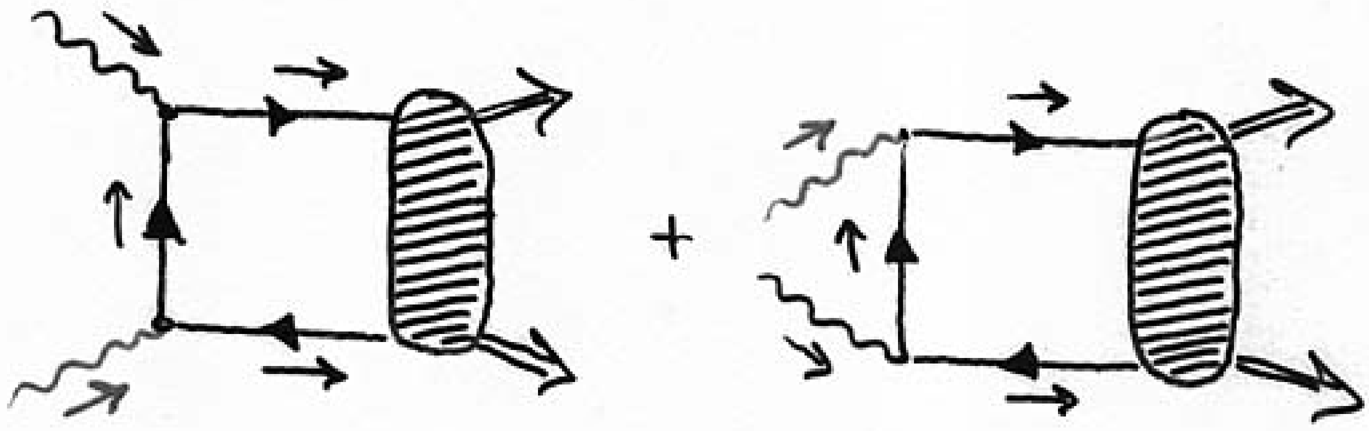
$$+ i \frac{\epsilon^T_{\alpha\beta}\Delta_\alpha}{P.n} \frac{e_1^\beta(e_2.n)+e_2^\beta(e_1.n)}{m^2} H_4^{\rho\rho,A}(y)$$

for the axial tensor structures

Here, $\epsilon^T_{\alpha\beta} \equiv \epsilon_{\alpha\beta\gamma\delta} P_\gamma n_\delta$

Amplitude of $\gamma\gamma \to \rho^0\rho^0$ subprocess

Diagrams:



Amplitude:

$$T_{\mu\nu} = \int_0^1 \frac{dy}{y(1-y)} \left[g^T_{\mu\nu}(1-2y)\,\mathbb{V}(y,\cos\theta,W^2) + \right.$$
$$\left. + \,\epsilon^T_{\mu\nu}\,\mathbb{A}(y,\cos\theta,W^2) \right]$$

where scalar and pseudo-scalar functions $\mathbb{V}$ and $\mathbb{A}$ denote the following

$$\mathbb{V}(y,\cos\theta,W^2) = \sum_i e_1^\alpha e_2^\beta\, V^{(i)}_{\alpha\beta}\, H_i^{\rho\rho,V}(y,\zeta(\cos\theta),W^2)$$

$$\mathbb{A}(y,\cos\theta,W^2) = \sum_i e_1^\alpha e_2^\beta\, A^{(i)}_{\alpha\beta}\, H_i^{\rho\rho,A}(y,\zeta(\cos\theta),W^2)$$

The squared and polarization averaged functions $|\mathbb{V}|^2$ and $|\mathbb{A}|^2$ which will appear in the differential cross-section read:

$$|\mathbb{V}|^2 = P^{\alpha_1\alpha_2}(p_1)\, P^{\beta_1\beta_2}(p_2)\, V^{(i)}_{\alpha_1\beta_1} H_i^{\rho\rho,V}\, V^{(j)}_{\alpha_2\beta_2} H_j^{\rho\rho,V},$$

$$|\mathbb{A}|^2 = P^{\alpha_1\alpha_2}(p_1)\, P^{\beta_1\beta_2}(p_2)\, A^{(i)}_{\alpha_1\beta_1} H_i^{\rho\rho,A}\, A^{(j)}_{\alpha_2\beta_2} H_j^{\rho\rho,A}$$

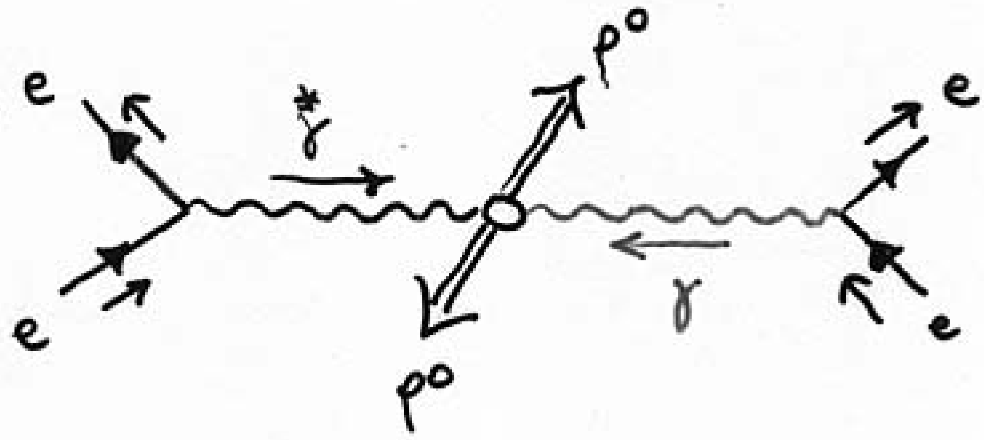
where

$$P_{\alpha\beta}(p) \stackrel{\text{def}}{=} \sum_{\lambda} e^{(\lambda)}_{\alpha}\, \overset{*}{e}{}^{(\lambda)}_{\beta} =$$

$$= -g_{\alpha\beta} + \frac{p_\alpha p_\beta}{m^2}$$

Differential Cross-Section

Diagrams:



Amplitude:

$$A(ee \to ee2\rho^0) = \sum_{i,j} \left[J_\mu(l,l')\, \overset{*}{\varepsilon}{}'^{(i)}_\mu \right] \frac{1}{q'^2}\, A_{(i,j)} \frac{1}{q^2} \left[\overset{*}{\varepsilon}{}^{(j)}_\nu\, J_\nu(k,k') \right]$$

Due to parity invariance there are only three independent helicity amplitudes:

$$\underbrace{A_{(+,+)}}_{\Downarrow\ \text{twist } 2}\ ,\ \underbrace{A_{(+,-)}\ ,\ A_{(+,0)}}_{\Downarrow\ \text{twist} > 2}$$

Square of modulus of amplitude reads:

$$|A(ee \to ee2\rho^0)|^2 = |A(e\gamma \to e2\rho^0)|^2 \frac{1}{q'^4}\, |A(e \to e\gamma)|^2$$

It is useful to introduce the integrated functions which take the forms:

$$\mathbb{V}(\cos\theta, W^2) = \int_0^1 dy \, \frac{1-2y}{y(1-y)} \, \mathbb{V}(y, \cos\theta, W^2)$$

$$\mathbb{A}(\cos\theta, W^2) = \int_0^1 dy \, \frac{1}{y(1-y)} \, \mathbb{A}(y, \cos\theta, W^2)$$

In this case, <u>the amplitude</u> is expressed as

$$T_{\mu\nu} = g^{T}_{\mu\nu} \, \mathbb{V}(\cos\theta, W^2) + \epsilon^{T}_{\mu\nu} \, \mathbb{A}(\cos\theta, W^2)$$

The next objects are <u>the helicity amplitudes</u>:

$$A_{(i,j)} = \underline{\underline{\varepsilon'^{(i)}_{\mu}}} \, \underline{\underline{\varepsilon^{(j)}_{\nu}}} \, T_{\mu\nu}$$

where

$$\varepsilon'^{(\pm)}_{\mu} = \left(0, \frac{\mp 1}{\sqrt{2}}, \frac{+i}{\sqrt{2}}, 0\right)$$

$$\varepsilon^{(\pm)}_{\mu} = \left(0, \frac{\mp 1}{\sqrt{2}}, \frac{-i}{\sqrt{2}}, 0\right), \quad \varepsilon^{(0)}_{\mu} = \left(\frac{|q|}{\sqrt{Q^2}}, 0, 0, \frac{q_0}{\sqrt{Q^2}}\right)$$

$$Q^2 = -q^2$$

Finally, we write for the cross-section:

$$\frac{d\sigma(ee\to ee2\rho^0)}{dQ^2} = \frac{\alpha^4}{16\pi^2}\int_0^1 dx_2\, F_{WW}(x_2)\,\cdot$$

$$\left\{ \frac{1}{16\, x_2^2\, E_2^4\, Q^2} \int_{W^2_{min}}^{W^2_{max}} dW^2 \beta\, F_{(+,+)}(W^2) \; - \right.$$

$$\left. - \frac{1}{2x_2 E_2^2 Q^2} \int_{W^2_{min}}^{W^2_{max}} dW^2 \frac{\beta F_{(+,+)}(W^2)}{Q^2+W^2} + \frac{2}{Q^2}\int_{W^2_{min}}^{W^2_{max}} dW^2 \frac{\beta F_{(+,+)}(W^2)}{(Q^2+W^2)^2} \right\}$$

where $F_{WW}(x_2)$ – Weizsacker-Williams distribution function, and

$$F_{(+,+)}(W^2) = \int d(\cos\theta)\, 4 \left\{ |\mathbb{V}(\cos\theta, W^2)|^2 + \right.$$

$$\left. + |\mathbb{A}(\cos\theta, W^2)|^2 \right\}$$

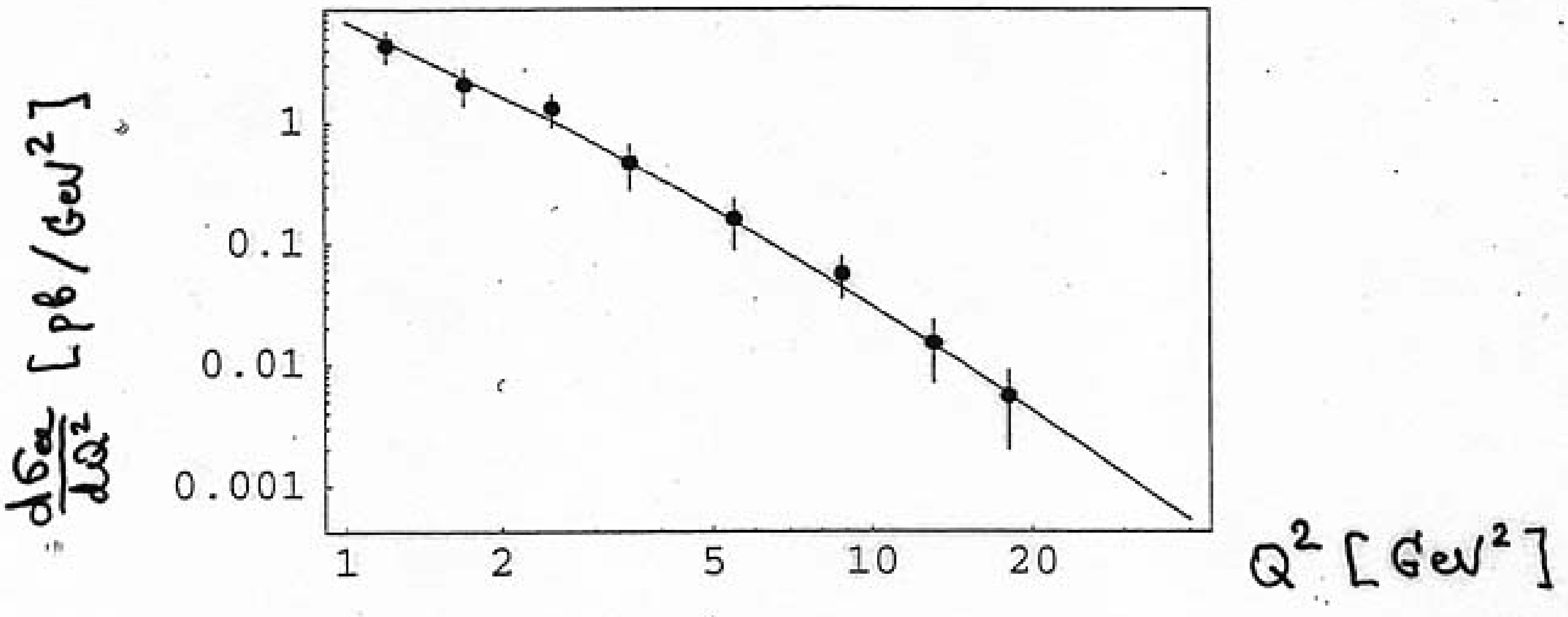


Figure 3: Cross-section $d\sigma/dQ^2[pb/GeV^2]$ in logarithmical scale. The theoretical cross-section is plotted for the best fitted parameters which are $C_1 = 1.$, $W_1 = 2.9$ GeV and $W_2 = 1.2$ GeV

$1.1 \le$ [illegible] ≤ 5.0 Ge

$$\frac{d\sigma}{dQ^2}(ee \to ee2\rho^0) = \frac{\alpha^4}{16\pi^2} C_1 \int_0^1 dx_2 \, F_{WW}(x_2)$$

$$\left\{ \frac{1}{16 x_2^2 E_2^4 Q^2} - \frac{1}{2 x_2 E_2^2 Q^2 (Q^2 + \langle W_1 \rangle^2)} + \frac{2}{Q^2 (Q^2 + \langle W_2 \rangle^2)^2} \right\}$$

The best fit correspond to

$C_1 = 1.0 \pm 0.12$ GeV^2 $\quad \langle W_2 \rangle = 1.2 \pm 0.08$ GeV

$\langle W_1 \rangle = 2.9 \pm 1.8$ GeV

$\chi^2 / _{d.o.f.} = 0.25$