Spin density matrix elements in vector meson leptoproduction

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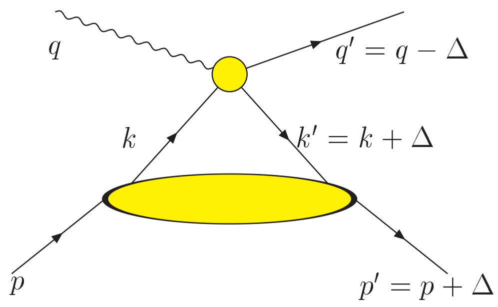
1 Introduction

- Modified PA
  - transverse degrees of freedom in wave function; hard subprocess
  - Sudakov suppression
- Physical observables
  - -cross sections of light VM production
  - SDME

2 Leptoproduction of Vector Mesons in GPD -(Modified PA)

The process of VM production:



We calculate the $L \to L$, $T \to T$ and $T \to L$ amplitudes which are important in analyses of cross section and spin observales. In calculations the k- dependent wave function is used

$$\hat{\Psi}_V = g[(\not{V} + M_V)\not{\epsilon}_V + \frac{2}{M_V}\not{V}\not{\epsilon}_V\not{K} - \frac{2}{M_V}(\not{V} - M_V)(\epsilon_V \cdot K)]\phi_V(k,\tau). \quad (1)$$

J. Bolz, J. Körner and P. Kroll, 1994

- V is a vector meson momentum and M_V is its mass
- ϵ_V is a meson polarization vector and K is a quark transverse momentum

In the small x region the gluon contributions to the amplitudes $\gamma^*_\mu \to V'_\mu$ are important (JI notation) :

$$\begin{aligned}
\mathcal{M}^{V(g)}_{\mu'+,\mu+} &= \frac{e}{2}\mathcal{C}_V \sqrt{1-\xi^2}\,(1+\xi) \int_0^1 \frac{d\bar{x}}{(\overline{x}+\xi)(\overline{x}-\xi+i\hat{\varepsilon})} \\
&\times \left\{ \left[\mathcal{H}^{(g)}_{\mu'+,\mu+} + (-1)^{\mu'+\mu}\,\mathcal{H}^{(g)}_{-\mu'+,-\mu+} \right] H^g(\overline{x},\xi,t) \right. \\
&+ \left. \left[\mathcal{H}^{(g)}_{\mu'+,\mu+} - (-1)^{\mu'+\mu}\,\mathcal{H}^{(g)}_{-\mu'+,-\mu+} \right] \widetilde{H}^g(\overline{x},\xi,t) \right\} , \qquad (2)
\end{aligned}$$

The flavor factors are $\mathcal{C}_\rho = 1/\sqrt{2},\ \mathcal{C}_\phi = -1/3$.

EXAMLE: TT case. The hard scattering amplitudes read

$$\mathcal{H}^{V(g)}_{\mu+,\mu+} = \frac{2\pi\alpha_s(\mu_R) f_V}{N_c} \int_0^1 d\tau \int \frac{d^2\mathbf{k}_\perp}{16\pi^3} \phi_V(\mathbf{k}_\perp,\tau)\; T^{(g)}_\mu(x,\xi,\mathbf{k}_\perp,Q^2)\,. \qquad (3)$$

Kroll, Raulfs '96

$$\phi_V(\mathbf{k}_\perp,\tau) = 8\pi^2\sqrt{2N_c}\,a_V^2\,\exp\left[-a_V^2\,\frac{\mathbf{k}_\perp^2}{\tau\bar{\tau}}\right]. \qquad (4)$$

The predominant $\propto H^g(\overline{x},\xi,t)$ combination to hard scattering kernels:

$$T^g_+ + T^g_- = \frac{(\overline{x}+\xi)\,(\overline{x}-\xi)\,\tau\,\bar{\tau}\,\left(y\,\bar{y} + y^2\tau\,\bar{\tau} + \bar{y}^2\tau\,\bar{\tau}\right)}{2\,\xi^2\,D}\,\frac{\mathbf{k}_\perp^2}{m_V}\,Q^{10} \qquad (5)$$

The product of propagator denominators reads

$$D = \left(\mathbf{k}_\perp^2 + \bar\tau\, Q^2\right)\,\left(\mathbf{k}_\perp^2 + \tau\, Q^2\right)\,\left(\mathbf{k}_\perp^2 + \bar y\,\bar\tau\, Q^2 - i\hat\varepsilon\right)$$
$$\times\left(\mathbf{k}_\perp^2 + y\,\bar\tau\, Q^2 - i\hat\varepsilon\right)\,\left(\mathbf{k}_\perp^2 + \tau\, y\, Q^2 - i\hat\varepsilon\right)\,\left(\mathbf{k}_\perp^2 + \tau\,\bar y\, Q^2 - i\hat\varepsilon\right)\,.$$

The y and $\bar y$ are defined by

$$y = (x+\xi)/(2\xi)\,, \qquad \bar y = 1 - y\,. \tag{6}$$

In calculation

- We use double distributions for GPDs Radyushkin '99 and take a factorising ansatz for the double distributions $f(x,y,t)$

$$f^g(x,y,t) = 6\frac{y(1-x-y)}{(1-x)^3}\, xg(x)\, f(t)\,. \tag{7}$$

-CTEQ5M parameterization for gluon DF.

- Sudakov suppression of large quark-antiquark separations. These effects suppress contributions from the end-point regions , in which one of the partons in the meson wave function becomes soft and where factorization breaks down .

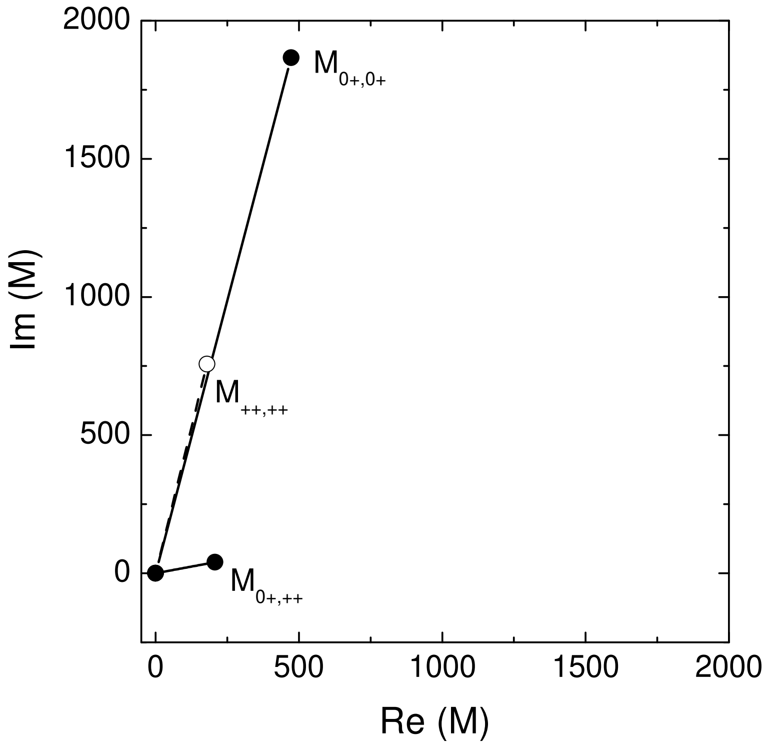
The model leads to the following form of helicity amplitudes

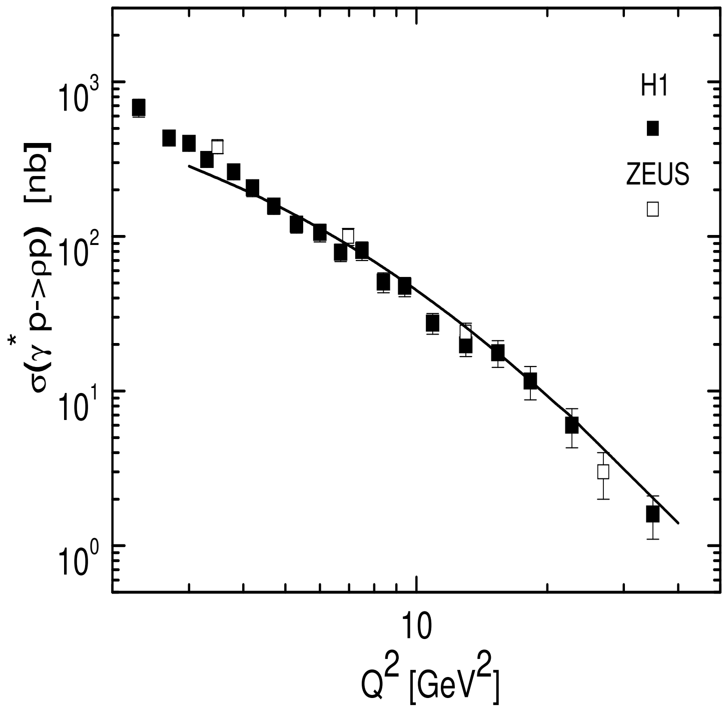
$$\begin{aligned}
\mathrm{L}\to\mathrm{L}: &\qquad \mathcal{M}^{V(g)}_{0\,\nu,0\,\nu} \propto 1 \quad \text{–large Im},\\
\mathrm{T}\to\mathrm{L}: &\qquad \mathcal{M}^{V(g)}_{0\,\nu,+\nu} \propto \frac{\sqrt{-t}}{Q} \quad \text{–large Re},\\
\mathrm{T}\to\mathrm{T}: &\qquad \mathcal{M}^{V(g)}_{+\nu,+\nu} \propto \frac{\mathbf{k}_\perp^2}{Q^2} \quad \text{–large Im},\\
\mathrm{L}\to\mathrm{T}: &\qquad \mathcal{M}^{V(g)}_{+\nu,0\,\nu} \propto \frac{\sqrt{-t}}{Q}\,\frac{\mathbf{k}_\perp^2}{Q^2}\,,\\
\mathrm{T}\to-\mathrm{T}: &\qquad \mathcal{M}^{V(g)}_{-\nu,+\nu} \propto \frac{-t}{Q^2}\,\frac{\mathbf{k}_\perp^2}{Q^2}\,.
\end{aligned} \tag{8}$$

Thus, the $L \to T$ and $T \to -T$ transitions should be small and we shall neglect these amplitudes .

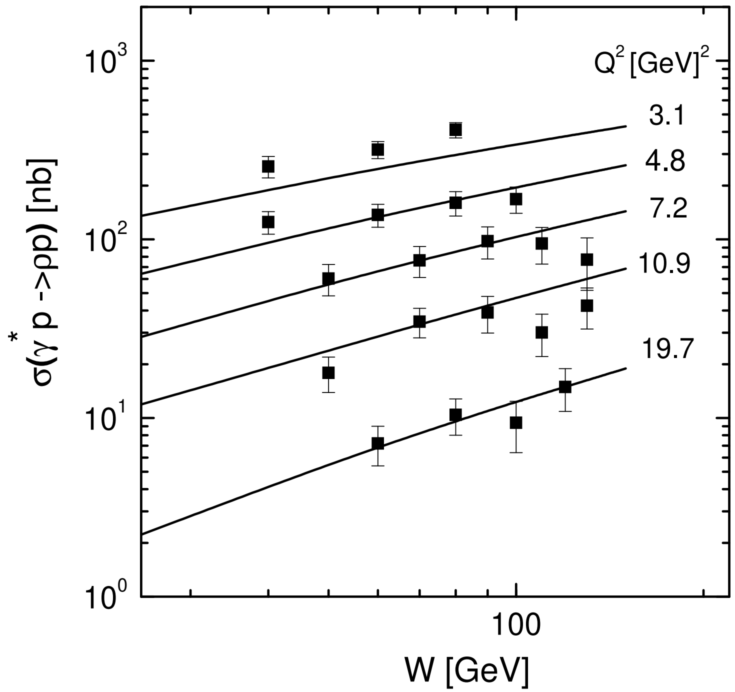
Estimations for the amplitudes in the modified perturbative approach for the production of ρ mesons are obtained using $\Lambda_{QCD} = 0.22\,\mathrm{GeV}$,

- ρ meson production $f_\rho = .216\,\mathrm{GeV}$, $a_\rho = 0.522\,\mathrm{GeV}^{-1}$.
- ϕ meson production $f_\phi = .237\,\mathrm{GeV}$, $a_\phi = 0.45\,\mathrm{GeV}^{-1}$.

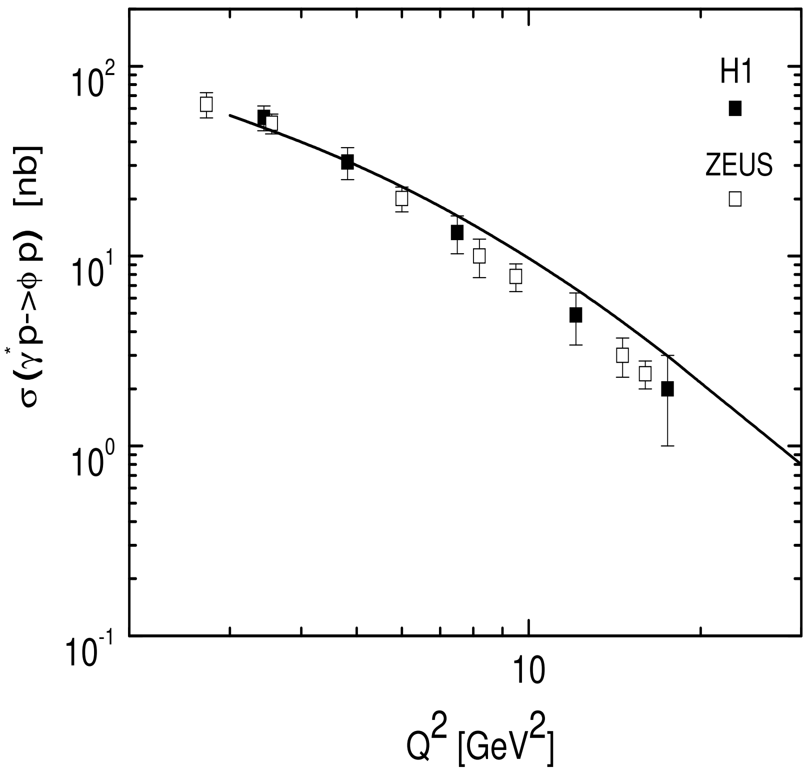




The cross section for $\gamma^* p \to \rho^0 p$ vs. Q^2 for fixed values of $< W >=$ 75 GeV. Data are taken from H1& ZEUS.



The cross section for $\gamma^* p \to \rho^0 p$ vs. W for fixed values of Q^2. Data are taken from H1.



The cross section for $\gamma^* p \to \phi p$ vs. Q^2 for fixed values of $< W >= 75\,\mathrm{GeV}$. Data are taken from H1& ZEUS.

3 Spin density matrix elements

Using $L \to L$, $T \to T$ and $T \to L$ amplitudes we define spin observables

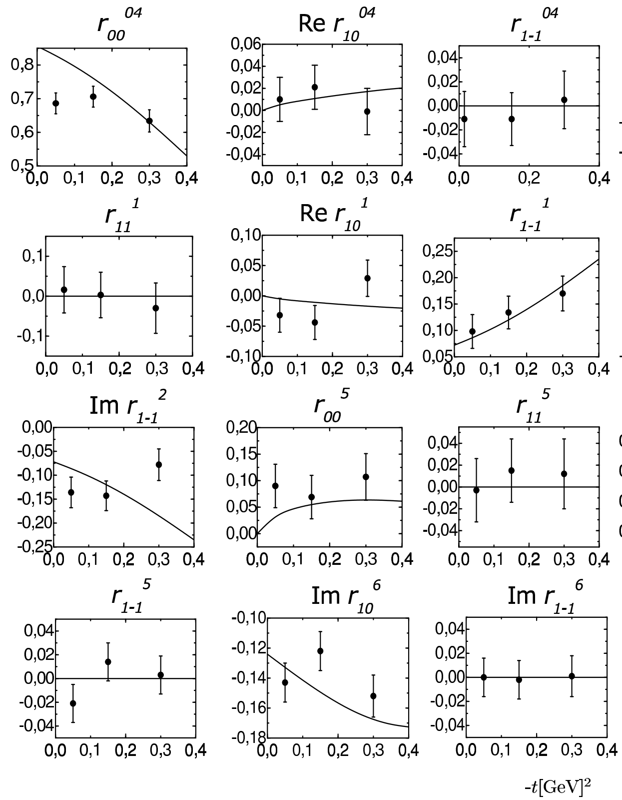
$$
\begin{aligned}
N_L &= 2|\mathcal{M}^{V(g)}_{0\,+,0\,+}|^2\,, \\
N_T &= \sum_\nu \left[|\mathcal{M}^{V(g)}_{+\nu,+\nu}|^2 + |\mathcal{M}^{V(g)}_{0\,\nu,+\nu}|^2\right]\,, \\
r^{04}_{00} &= \frac{1}{N_T + \varepsilon N_L} \sum_\nu (|\mathcal{M}^{V(g)}_{0\nu,,+\nu}|^2 + \varepsilon\,|\mathcal{M}^{V(g)}_{0\nu\,,0\nu}|^2) \\
& \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned} \tag{9}
$$

$$
R = \frac{N_L}{N_T} \tag{10}
$$

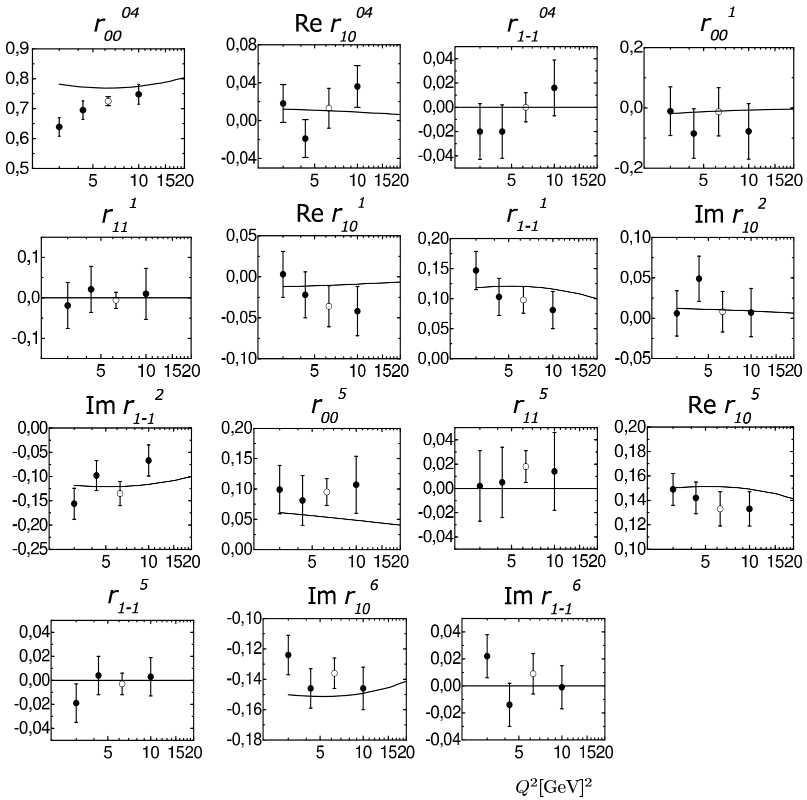
Different diffraction peak slopes are proposed for LL and TT amplitudes.

$$
B_{TT} = B_{LL}/3 \tag{11}
$$

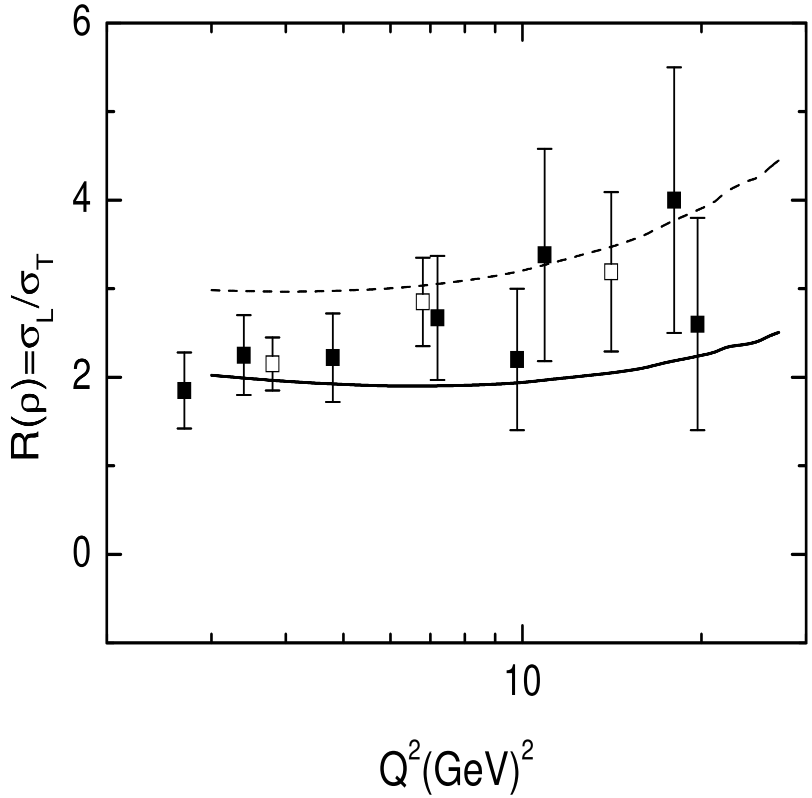
Good description of t dependence of SDME .



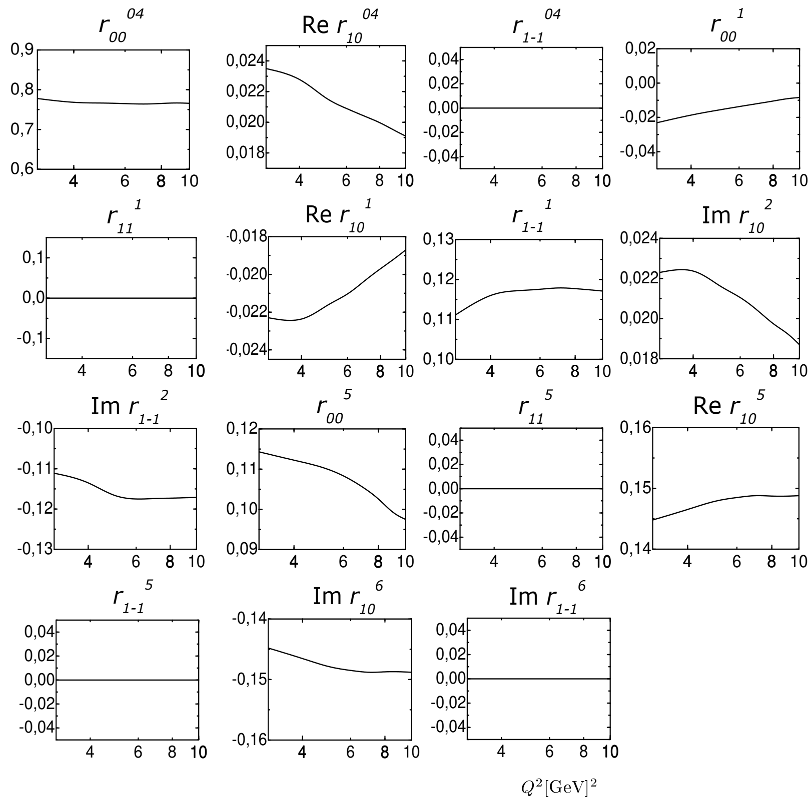
t- dependence of SDME of ρ production at $Q^2 = 5\,\mathrm{GeV}^2$ and $< W >= 75\,\mathrm{GeV}$. Data are taken from H1.



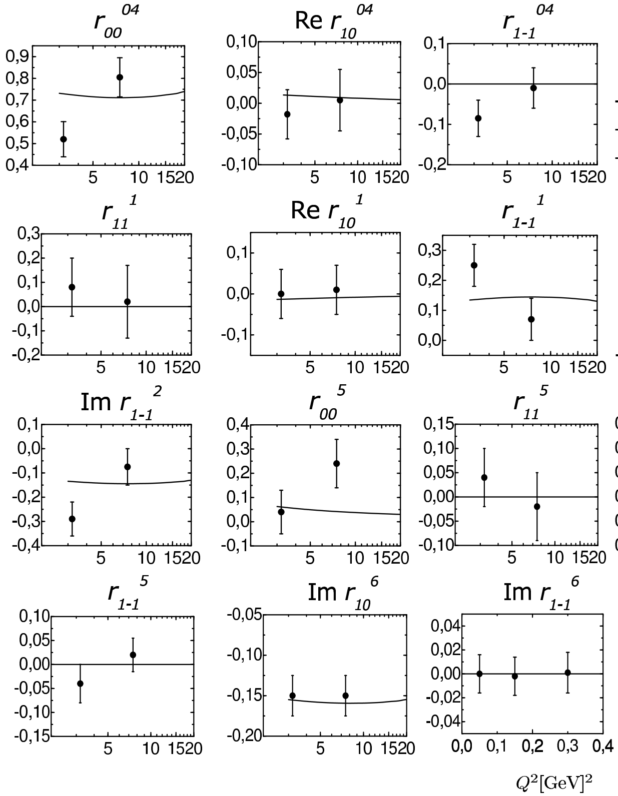
Q^2 dependence SDME of ρ production at $< t >= -.15\,\mathrm{GeV}^2$ and $< W >= 75\,\mathrm{GeV}$. Data are taken from H1 & ZEUS.



Q^2 dependence R of ρ production at $< W >= 75\,\mathrm{GeV}$.
Full curve -from integrated over t cross section,
dashed curve for fixed $t = -.15\,\mathrm{GeV}^2$. Data are taken from H1 & ZEUS.



Q^2 dependence SDME of ρ production at $< t >= -.15\,\mathrm{GeV}^2$ and $< W >= 10\,\mathrm{GeV}$. COMPASS energy range.



Q^2 dependence SDME of ϕ production at $< t >= -.15\,\mathrm{GeV}^2$ and $< W >= 75\,\mathrm{GeV}$. Data are taken from H1.

4 Conclusion

- Modified PA which consider - transverse degrees of freedom and Sudakov suppressions in the subprocess give reasonable description of cross section and spin observables for light VM production in GPD approach.
- Further experimental efforts to reduce errors in SDME are important. Study of t dependence of SDME -different slopes of amplitudes.
- COMPASS future eRHIC ???