The aim of the present work is to present an effective field theory description of the conversion transition of the vector meson $V$ into the pseudoscalar $P$ and the lepton pair $l^+ l^-$. The lepton pair is produced by the virtual photon $\gamma^*$: $V \to \gamma^* P l^+ l^-$. The most recent information on the former process comes from the CERN SPS experiment NA 60 [1]. The knowledge given by Novosibirsk experiment CMD-2 [2] is less precise. The measured quantity is the transition form factor $F_{V \to P l^+ l^-}(Q^2)$ as a function of the lepton-pair invariant mass $Q^2$. The most recent theoretical advances in the modeling of the $V \gamma^* l^+ l^-$ transition form factors [3-5] were partly motivated by a drastic discrepancy between a novel CERN SPS NA 60 experiment data and a naive VMD ansatz prediction for the $\omega \to \pi^0 \gamma$ transition form factor. We would like to remark that new precise data from KLOE experiment will appear soon [6] and serve as an important test of the models.

**Effective Lagrangian**

For the odd-intrinsic-parity interactions of vector mesons we use chiral Lagrangian in vector formulation for spin-1 fields [7, 8]. The Lagrangian terms relevant for the calculation of $F_{V \to P l^+ l^-}(Q^2)$:

- $\mathcal{L}_{V\gamma} = -e f_V B^* \rho^* (\rho_{\mu\nu} + 1/3 \delta_{\mu\nu} - 2 \gamma^5 \phi_{\mu\nu})$, where $\phi_{\mu\nu} = \partial_\mu \phi_{\nu} - \partial_\nu \phi_{\mu}$.

- $\mathcal{L}_{\rho\gamma} = -4 e f_{\rho} \rho_{\mu\nu} (\gamma^\mu \phi_{\nu\rho} + 3 \omega_{\rho\nu} + 3 \epsilon_{\omega\rho\lambda} \phi_{\lambda} \rho_{\mu\nu})$, where $\epsilon_{\rho\omega\mu} = \text{tot. antisymmetric Levi-Civita tensor}$.

- Short-distance constraint [9]:

  $$\sqrt{2} h_V - \sigma_V f_V = 0.$$ 

Radiative decays $V \to \pi^0 \gamma$

- These decays provide an access to the value of the model parameter $h_V$ via the partial width:

  $$\Gamma (\omega \to \pi^0 \gamma) = \frac{4 \alpha M_\omega^3 h_V^2}{3 f_\pi^2} \left(1 - \frac{m_\pi^2}{M_\omega^2}\right)^3.$$ 

- The PDG value for widths [10]

  - $\Gamma (\rho \to \pi^0 \gamma) = (89.46 \pm 11.94) \text{ keV}$
  - $\Gamma (\omega \to \pi^0 \gamma) = (702.97 \pm 24.67) \text{ keV}$

roughly follow the SU(3) prediction of its ratio. The extracted coupling constant is $h_V = 0.041 \pm 0.003$.

The knowledge given by Novosibirsk experiment CMD-2 [2] is

- The $\omega \to \pi^0 \gamma$ decay width vanishes as long as the $\phi$-meson is a pure $s\bar{s}$ state. The measured width $\Gamma (\omega \to \pi^0 \gamma) = (5.41 \pm 0.26) \text{ keV}$ is, however, significantly different from zero.

- Thus $\omega$-mixing ansat may be assumed and compared with the data. Estimated mixing parameter: $\epsilon_{\omega\phi} = (5.79 \pm 0.17) \times 10^{-2}$.

**OZI-forbidden process**

- In the following we include only the imaginary part of the loop contribution. This will be the dominant term for the energy-dependent width

  $$\Gamma_{\text{tot}, \rho}(Q^2) = -M_\rho^{-1} \text{ Im } \Pi_\rho(Q^2).$$

- The equation for the modified EM coupling:

  $$f_\rho(Q^2) = f_V - \frac{1}{e Q^2} \sum_c \text{ Im } \Pi_{\rho}(e^c)(Q^2).$$

The coupling constant $f_\rho$ could be found from

$$\Gamma (\rho \to e^+ e^-) = \frac{e^2 M_\rho}{12 \pi} (f_\rho(Q^2) = M_\rho^2)^2.$$ 

According to the PDG value for the width:

$$f_\rho = 0.20173 \pm 0.00086.$$ 

**Results**

- In the region of interest the most important contribution to $\Pi_\rho(Q^2)$ consist of the pion loop vertex correction to $\gamma^* p$ coupling [11]:

- The transition form factors can be extracted from the lepton-pair invariant mass spectrum $dV_{\omega / 2} / dQ^2$, where $\sqrt{Q^2} = M_\pi = M_{\pi^0}$. 

- Only the normalized FF's are known:

  $$F_{V \to P l^+ l^-}(Q^2) = \frac{F_{V \to P l^+ l^-}(0)}{\sqrt{Q^2}}.$$ 

- We include the direct $\omega - \pi^0 \gamma^*$-coupling and subsequent $\rho^0$ conversion contributing to the Dalitz decay $\omega \to \pi^0 \mu^+ \mu^-$. According to the Lagrangian terms, the form factor:

  $$F_{\omega - \pi^0 \gamma^*}(Q^2) = 1 - \frac{\sigma_V f_\rho(Q^2)}{2 \sqrt{2} h_V} Q^2 D_\rho(Q^2).$$

- An additional energy dependence of the EM coupling $f_\rho(Q^2)$ arises due to higher-order corrections. The $\rho$-meson propagator is

  $$D_\rho(Q^2) = (Q^2 - M_\rho^2 - \Pi_\rho(Q^2))^{-1},$$ 

  where $\Pi_\rho(Q^2)$ is the self-energy operator.

**Summary**

- Strong contradiction with the data in the region of $M_\gamma^* > 0.4$ GeV. The $\gamma V$ vertex modification does not improve the result.

- We look forward to develop a more realistic model.

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