EPJ Web of Conferences **81**, 05001 (2014)
DOI: 10.1051/epjconf/20148105001
© Owned by the authors, published by EDP Sciences, 2014

Electromagnetic structure of vector mesons

C. Adamuščín[1,a], S. Dubnička[1], and A. Z. Dubničková[2]

[1] *Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia*
[2] *Depart. of Theoretical Physics, Comenius University, Bratislava, Slovakia*

Abstract. Electromagnetic structure of the complete nonet of vector mesons ($\rho^0, \rho^+, \rho^-, \omega, \phi, K^{*0}, K^{*+}, \bar{K^{*0}}, K^{*-}$) is investigated in the framework of the Unitary and Analytic model and insufficient experimental information on it is discussed.

1 Introduction

According to the SU(3) classification of hadrons the spin 1^- particles are included in a vector meson nonet. The main purpose of our contribution is to outline a description of the electromagnetic (EM) structure of vector mesons within the framework of the universal Unitary and Analytic (U&A) model with respect to the known theoretical constrains and an insufficient experimental information.

In general the EM structure of all vector particles, owing to the spin value 1, is completely described by three independent EM form factors (FFs).

Since the neutral vector mesons ρ^0, ω, ϕ from the nonet under consideration are self-conjugate particles obeying the crossing relation, their EM FFs are identically equal to zero in the whole region of definition. As a result, further only the EM structure of $\rho^+, \rho^-, K^{*0}, K^{*+}, \bar{K^{*0}}, K^{*-}$ vector mesons will be investigated.

2 Asymptotic behavior of vector meson structure functions

According to the quark model [1] the vector meson structure function $A(q^2)$ has the asymptotic behavior

$$(A(t))^{1/2}\Big|_{|t|\to\infty} \sim t^{1-n_q} = t^{-1}, \tag{1}$$

where $t = q^2$ and $A(t)$ is obtained from the differential cross section of the scattering (or e^+e^- annihilation) process of electron on a vector meson by the Rosenbluth separation. It can be decomposed into Sachs EM FFs

$$A(t) = \frac{2}{3}\eta G_M^2(t) + G_C^2(t) + \frac{8}{9}\eta^2 G_Q^2(t)$$

with $\eta = -t/4m_V^2$. Moreover it has been demonstrated [2] that at high q^2 the spin 1 particle EM FFs fulfill the following relations

$$G_C(t) : G_M(t) : G_Q(t) = \left(1 - \frac{2}{3}\eta\right) : 2 : -1. \tag{2}$$

[a] e-mail: cyril.adamuscin@savba.sk

This is an Open Access article distributed under the terms of the Creative Commons Attribution License 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article available at http://www.epj-conferences.org or http://dx.doi.org/10.1051/epjconf/20148105001

The latter two equations (1 and 2) imply that EM FFs of vector mesons have the following asymptotic behaviors

$$G_C(t)\Big|_{|t|\to\infty} \sim t^{-1}\ ,\ G_M(t)\Big|_{|t|\to\infty} \sim t^{-2}\ ,\ G_Q(t)\Big|_{|t|\to\infty} \sim t^{-2}. \tag{3}$$

3 Electromagnetic structure of the ρ^+, ρ^- vector mesons

Due to the conservation of G-parity one can saturate $\gamma^*\rho^+\rho^-$ vertex only with ρ meson and its excitations.

In order to satisfy asymptotic behavior given by (3) one needs to saturate "advanced" VMD model [3] with at least two neutral resonances ρ, ρ'

$$\begin{aligned} G^\rho_C(t) &= a^\rho_{C\rho}\frac{m^2_\rho}{m^2_\rho - t} + (G^\rho_C(0) - a^\rho_{C\rho})\frac{m'^2_\rho}{m'^2_\rho - t} \\ G^\rho_M(t) &= G^\rho_M(0)\frac{m^2_\rho}{m^2_\rho - t}\frac{m'^2_\rho}{m'^2_\rho - t}\ \ ;\ \ G^\rho_Q(t) = G^\rho_Q(0)\frac{m^2_\rho}{m^2_\rho - t}\frac{m'^2_\rho}{m'^2_\rho - t}, \end{aligned} \tag{4}$$

where $G_C(0) = 1, G_M(0), G_Q(0)$ are normalizations of the ρ^+ at $t = 0\,\mathrm{GeV}^2$ and $a^\rho_{C\rho} = \frac{f_{v\rho^+\rho^-}}{f_v}$ is ratio of the corresponding coupling constants. Now we apply U&A transformations to be explained in [4]

$$\frac{m^2_v}{m^2_v - t} \to \left(\frac{1 - W(t)^2}{1 - W^2_N}\right)^2 LH(W_v), \tag{5}$$

and one obtains the U&A parametrizations of the charged ρ EM FFs

$$\begin{aligned} G^\rho_C(t) &= \left(\frac{1 - W^\rho_C(t)^2}{1 - W^{\rho\ 2}_{C;N}}\right)^2 \left(a^\rho_{C\rho}LH(W^\rho_{C;\rho}) + (G^\rho_C(0) - a^\rho_{C\rho})LH(W^\rho_{C;\rho'})\right) \\ G^\rho_M(t) &= G^\rho_M(0)\left(\frac{1 - W^\rho_M(t)^2}{1 - W^{\rho\ 2}_{M;N}}\right)^4 LH(W^\rho_{M;\rho})LH(W^\rho_{M;\rho'}) \\ G^\rho_Q(t) &= G^\rho_Q(0)\left(\frac{1 - W^\rho_Q(t)^2}{1 - W^{\rho\ 2}_{Q;N}}\right)^4 LH(W^\rho_{Q;\rho})LH(W^\rho_{Q;\rho'}). \end{aligned} \tag{6}$$

The values of two unknown form factor normalizations $G^\rho_M(0), G^\rho_Q(0)$ have been predicted within the light front theory [5]. The parametrizations (6) contain also four free parameters $a^\rho_{C\rho}, t^\rho_{inC}, t^\rho_{inM}, t^\rho_{inQ}$ to be ratio of the coupling constants and three effective thresholds, which can be found by a comparison of (6) with a few experimental points on ρ meson helicity amplitudes [6].

4 EM structure of the $K^*(892)$ vector mesons

The $K^*(892)$ meson represents isodublet of particles $K^*(892)^+, K^*(892)^0$ and similarly to the nucleon EM FFs, its EM FFs can be decomposed into the isoscalar (S) and isovector (V) parts as follows

$$\begin{aligned} G^{K^{*+}}_C(t) &= G^{K^*S}_C(t) + G^{K^*V}_C(t)\ ,\ G^{K^{*0}}_C(t) = G^{K^*S}_C(t) - G^{K^*V}_C(t) \\ G^{K^{*+}}_M(t) &= G^{K^*S}_M(t) + G^{K^*V}_M(t)\ ,\ G^{K^{*0}}_M(t) = G^{K^*S}_M(t) - G^{K^*V}_M(t) \\ G^{K^{*+}}_Q(t) &= G^{K^*S}_Q(t) + G^{K^*V}_Q(t)\ ,\ G^{K^{*0}}_Q(t) = G^{K^*S}_Q(t) - G^{K^*V}_Q(t). \end{aligned} \tag{7}$$

The asymptotic behavior is alike the charged ρ meson case given by the conditions (3). To satisfy them one needs to saturate isoscalar EM FFs by two isoscalar vector mesons ω, ϕ and isovector EM form factors by two isovector vector mesons ρ, ρ'. After performing the same procedure as for the charged ρ meson we have constructed U&A model of the $K^*(892)$ meson EM structure

Isoscalar parts:

$$
\begin{aligned}
G_C^{K^*S}(t) &= \left(\frac{1-W_C^{K^*S}(t)^2}{1-W_{C;N}^{K^*S\,2}}\right)^2 \left(a_{C\omega}^{K^*S} LH(W_{C;\omega}^{K^*S}) + (G_C^{K^*S}(0) - a_{C\omega}^{K^*S}) LH(W_{C;\phi}^{K^*S})\right) \\
G_M^{K^*S}(t) &= G_M^{K^*S}(0)\left(\frac{1-W_M^{K^*S}(t)^2}{1-W_{M;N}^{K^*S\,2}}\right)^4 LH(W_{M;\omega}^{K^*S}) LH(W_{M;\phi}^{K^*S}) \\
G_Q^{K^*S}(t) &= G_Q^{K^*S}(0)\left(\frac{1-W_Q^{K^*S}(t)^2}{1-W_{Q;N}^{K^*S\,2}}\right)^4 LH(W_{Q;\omega}^{K^*S}) LH(W_{Q;\phi}^{K^*S}),
\end{aligned}
\tag{8}
$$

Isovector parts:

$$
\begin{aligned}
G_C^{K^*V}(t) &= \left(\frac{1-W_C^{K^*V}(t)^2}{1-W_{C;N}^{K^*V\,2}}\right)^2 \left(a_{C\rho}^{K^*V} LH(W_{C;\rho}^{K^*V}) + (G_C^{K^*V}(0) - a_{C\rho}^{K^*V}) LH(W_{C;\rho'}^{K^*V})\right) \\
G_M^{K^*V}(t) &= G_M^{K^*V}(0)\left(\frac{1-W_M^{K^*V}(t)^2}{1-W_{M;N}^{K^*V\,2}}\right)^4 LH(W_{M;\rho}^{K^*V}) LH(W_{M;\rho'}^{K^*V}) \\
G_Q^{K^*V}(t) &= G_Q^{K^*V}(0)\left(\frac{1-W_Q^{K^*V}(t)^2}{1-W_{Q;N}^{K^*V\,2}}\right)^4 LH(W_{Q;\rho}^{K^*V}) LH(W_{Q;\rho'}^{K^*V}).
\end{aligned}
\tag{9}
$$

It has eight free parameters $a_{C\rho}^{K^*V}, a_{C\omega}^{K^*S}, t_{inC}^{K^*V}, t_{inM}^{K^*V}, t_{inQ}^{K^*V}, t_{inC}^{K^*S}, t_{inM}^{K^*S}, t_{inQ}^{K^*S}$ and four unknown FF normalizations $G_M^{K^{*0}}(0), G_Q^{K^{*0}}(0), G_M^{K^{*+}}(0), G_Q^{K^{*+}}(0)$. Unlike the ρ meson case there are no corresponding experimental measurements on $K^*(892)$ meson EM form factors, therefore we can not carry out any comparison of the theoretical model with data and to determine those twelve free parameters.

Acknowledgements

The work was partly supported by Slovak Grant Agency for Sciences VEGA, grant No. 2/0158/13, by Slovak Research and Development Agency APVV, grant No. APVV-0463-12 and by Joint research project of Institute of Physics, SAS and Bogoliubov Laboratory of Theoretical Physics, JINR, No. 01-3-1070.

References

[1] V. J. Matveev, R. M. Muradian and A. N. Tavkhelidze, Nuovo Cim. Lett. **7** 719 (1973), S. J. Brodsky and G. R. Farrar, Phys. Rev. Lett. **31** 1153 (1973).

[2] S. J. Brodsky and J. R. Hiller, Phys. Rev. **D46** 2141 (1992).

[3] D. Dubnička, A. Z. Dubničková and P. Weisenpacher, Eur. Phys. J. **C32** 381 (2003).

[4] S. Dubnička, Acta. Phys. Pol. **B27** 2525 (1996).

[5] B. L. G. Bakker, Ho-Meoyng Choi and Chueng-Ryong Ji, Phys. Rev. **D65** 116001 (2002).

[6] B. Aubert et al., Phys. Rev. **D78** 071103 (2008).