

# $K^*(892)$ Electromagnetic Mass Anomaly\*

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**Abstract:** Electromagnetic masses of neutral  $K^*(892)$  may be larger than one of charged  $K^*(892)$ . It is unusual and is called  $K^*$ -EM-mass anomaly. We review the studies on this issue, and point out that  $K^*$ -mass splitting can be measured in BES accurately.

**Key words:** electromagnetic mass splitting; BES experiment; meson resonance

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## 1 $K^*(892)$

The isospin, spin and parity of meson resonance  $K^*(892)$  are  $I(J^P) = 1/2(1^-)$ . Its flavor  $SU(3)$  multiplets are  $\bar{K}^{*0} = \bar{d}\gamma_{\mu s}$ ,  $K^{*0} = \bar{s}\gamma_{\mu d}$ ,  $K^{*+} = \bar{s}\gamma_{\mu u}$  and  $K^{*-} = \bar{u}\gamma_{\mu s}$ . Among the meson-resonances,  $K^*(892)$  is only one whose mass difference between its isospin components has been determined in experiments although the error bar is still large. According to the 2000-PDG report,  $K^*$  mass splitting is<sup>[1]</sup>

$$m_{K^*(892)^0} - m_{K^*(892)^{\pm}} = (6.7 \pm 1.2) \text{ MeV}. \quad (1)$$

Note, this value is larger than the mass splitting between  $K^0$  and  $K^{\pm}$ ,

$$m_{K^0} - m_{K^{\pm}} = (3.995 \pm 0.034) \text{ MeV}. \quad (2)$$

## 2 Mass Splitting of Hadrons

Generally, for the  $SU(3)$  flavor multiplets of hadrons, the mass splittings between their isospin components are caused by two effects: (1)  $m_u \neq m_d$  (inequality of u- and d-quark masses); (2) the electromagnetic interactions inside hadrons. Then, the observing quantity of the splitting  $(\Delta m)_{\text{expt}}$  is

expressed as follows

$$(\Delta m)_{\text{expt}} = (\Delta m)_{\text{Q}} + (\Delta m)_{\text{EM}}, \quad (3)$$

where  $(\Delta m)_{\text{expt}}$  is the experimental value;  $(\Delta m)_{\text{Q}}$ , the contributions due to u-d quark mass difference, and  $(\Delta m)_{\text{EM}}$  is due to electromagnetic interactions, or EM-mass difference. The theoretical predictions of  $(\Delta m)_{\text{Q}}$  and  $(\Delta m)_{\text{EM}}$  are model-dependent. They reflect the effects of internal structures of hadrons and the hadron dynamics.

## 3 EM-mass Anomaly

Usually, the EM-masses of neutral hadrons are less than one of their charged partners. For instance, the EM-masses of neutron,  $\pi^0$  and  $K^0(\bar{K}^0)$  are less than the EM-masses of proton,  $\pi^{\pm}$  and  $K^{\pm}$  respectively<sup>[2-4]</sup>. However, some theoretical studies show that the EM-mass of neutral  $K^*(892)$  may be larger than the EM-mass of charged  $K^*(892)$ . This is very unusual. In Ref. [5], we called it as  $K^*(892)$  EM-mass anomaly.

## 4 Estimation of EM-mass Splitting of $K^*(892)$

Theoretically,  $(\Delta m)_{\text{Q}}$  can be calculated in

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some models. By using Eq. (3) and experimental data  $(\Delta m)_{\text{expt}}$ , then, one can predict  $(\Delta m)_{\text{EM}}$ . There are two studies to estimate  $(\Delta m)_Q$  for  $K^*$  in the literature:

(1) Schechter et al<sup>[6]</sup> use an effective theory of hadrons to get  $(\Delta m)_Q$  is in the region from 2.04 MeV to 6.78 MeV. And its best parameter fitting result is

$$(m_{K^{*0}} - m_{K^{*\pm}})_Q = 4.47 \text{ MeV}. \quad (4)$$

This estimation indicates that so long as  $(m_{K^{*0}} - m_{K^{*\pm}})_{\text{expt}} > 6.78 \text{ MeV}$ , the  $K^*$ -EM-anomaly exist surely. And under the best parameter fitting, the condition for the anomaly becomes  $(m_{K^{*0}} - m_{K^{*\pm}})_{\text{expt}} > 4.47 \text{ MeV}$ . Consequently, from Eq. (1), it can be seen that the experiment favors to support  $(m_{K^{*0}} - m_{K^{*\pm}})_{\text{EM}} > 0$ , i. e., there exist  $K^*$ -EM-mass anomaly. But, because the error bar is still large, more precise experimental measurement for  $K^*$  mass splitting is necessary.

(2) Using Li's chiral quark model<sup>[7]</sup>, Gao and Yan found out<sup>[8]</sup> that

$$(m_{K^{*0}} - m_{K^{*\pm}})_Q \simeq \frac{1}{2} (m_d - m_u). \quad (5)$$

From  $\rho^0$ - $\omega$  mixing, they found out further

$$m_d - m_u = (6.14 \pm 0.36) \text{ MeV}. \quad (6)$$

Thus, they predict

$$(m_{K^{*0}} - m_{K^{*\pm}})_Q = (3.07 \pm 0.18) \text{ MeV}. \quad (7)$$

Consequently, so long as  $(m_{K^{*0}} - m_{K^{*\pm}})_{\text{expt}} > 3.25 \text{ MeV}$ , the  $K^*$ -EM-mass anomaly exists. Comparing with Eq. (1), we see that the present data support there exist such an anomaly in Li's chiral quark model.

## 5 Significance

$K^*$ 's are composite particles with quark structures. Neutral particle  $K^{*0}(892)$  is composited of positive charged  $\bar{s}$ -quark and negative charged  $d$ -quark. Due to the interactions between quarks, the

distribution of the positive charge "quark cloud" inside  $K^{*0}$  is generally different from one of the negative charge "quark cloud". This is the reason why the neutral particle  $K^{*0}$  is possessed of EM-mass (or EM-self energies). As the distribution of the positive charge cloud just overlaps one of the negative's, its EM-mass would vanish. As the overlapping is few, or they are totally dis-overlapped, the EM-mass of  $K^{*0}$  will become so large that it is bigger than the EM-mass of  $K^{*\pm}$ . This is the case of  $K^*$ -EM-mass anomaly. Obviously, this anomaly effect reflects important structure information on the quark distribution inside vector meson resonance. Hence, it is valuable for hadron physics and for QCD at middle energies to study this topic experimentally and theoretically.

## 6 Principle to Measure $K^*(892)$ Mass Splitting in BES at BEPC

BES at BEPC has gathered about  $5 \times 10^7$   $J/\Psi$  events. Therefore, it is practicable to take  $J/\Psi$  as the source of  $K^*(892)$  and to study its mass-splitting accurately. The branch ratio for  $J/\Psi \rightarrow K^\mp K^{*\pm}$  is  $5 \times 10^{-3}$ ; for  $J/\Psi \rightarrow \bar{K}^0 K^{*0}$ , it is  $4.2 \times 10^{-5}$ ; for  $J/\Psi \rightarrow K\bar{K}\pi$ ,  $6 \times 10^{-3}$ ; for  $K^* \rightarrow K\pi$ , it is about 100%<sup>[1]</sup>. Therefore, by using three-body decay processes of  $J/\Psi \rightarrow K\bar{K}\pi$ , we can determine the locations of resonance  $K^\mp \pi^\pm (= K^{*0} \text{ or } \bar{K}^{*0})$  and resonance  $K^0 \pi^\pm (= K^{*\pm})$  respectively. The event number of  $J/\Psi \rightarrow K\bar{K}\pi$  in BES is about  $10^5$ . It is expected to decrease the error for the splitting to 1 MeV or below 1 MeV. This should be a meaningful experiment in hadron physics. As the apparatuses of energy measure in BES are improved further in the near future, one could expect more accurate results on this object.

## References:

- [1] Particle Data Group.  $K^*(892)$ [J]. Euro Phys Jour, 2000. C15: 528-530.
- [2] Li B A, Yan M L, Liu K F. Electromagnetic Mass Differences of  $N$  and  $\Delta$  in the Skyrme Model[J]. Phys Lett, 1986, B177: 409-412.
- [3] Das T, Guralnik G S, Mathur V S, *et al.* Electromagnetic Mass Difference of Pions[J]. Phys Rev Lett, 1967, 18: 759-761.
- [4] Gao D N, Li B A, Yan M L. Electromagnetic Mass Splittings of  $\pi$ ,  $K$ ,  $a_1$ ,  $K(1400)$ , and  $K^*(892)$ [J]. Phys Rev, 1997, D56: 4 115-4 132.
- [5] Yan M L, Gao D N. Electromagnetic Mass Anomaly of  $K^*(892)$  in the Massive Yang-Mills Theory[J]. Commun Theor Phys, 1998, 30: 577-582.
- [6] Schechter J, Subbaraman A, Weigel H. Effective Hadron Dynamics: From meson masses to the proton spin puzzle[J]. Phys Rev, 1993, D48: 339-355.
- [7] Li B A.  $U(2)_L \times U(2)_R$  Chiral Theory of Mesons[J]. Phys Rev, 1995, D52: 5 165-5 183; Li B A.  $U(3)_L \times U(3)_R$  Chiral Theory of Mesons[J]. Phys Rev, 1995, D52: 5 184-5 193.
- [8] Gao D N, Yan M L.  $\rho^2-\omega$  Mixing in  $U(3)_L \times U(3)_R$  Chiral Theory of Mesons[J]. Eur Phys J, 1998, A3: 293-298.

## $K^*(892)$ 电磁质量反常\*

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**摘 要:** 电中性的  $K^*(892)$  电磁质量可以大于带电荷的  $K^*(892)$ 。这是异乎寻常的现象, 将被称为  $K^*$ -电磁质量反常。评述了这个课题, 并指出  $K^*$  的质量劈裂可以在北京谱仪(BES)上作精密测量。

**关键词:** 电磁质量劈裂; BES 实验; 介子共振态

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