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Letter

Letter

η, η' mixing angle and η' gluonium content extraction from the KLOE R_ϕ measurement*

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Abstract. In this report the extraction of the η, η' mixing angle and of the η' gluonium content from the $R_\phi = Br(\phi(1020) \to \eta'\gamma)/Br(\phi(1020) \to \eta\gamma)$ is updated. The η' gluonium content is estimated by fitting R_ϕ, together, with other decay branching ratios. The extracted parameters are: $Z_G^2 = 0.12 \pm 0.04$ and $\varphi_P = (40.4 \pm 0.9)^\circ$.

PACS. 14.40.Aq π, K, and η mesons – 13.20.Jf Decays of other mesons – 12.39.Mk Glueball and non-standard multi-quark/gluon states

1 Introduction

The η'-meson, being a pure $SU(3)$ singlet, has been considered for years the meson within which a gluon condensate contribution can show up. In this paper we try to extract the gluon condensate and the η, η' mixing angle in the constituent quark model using the approach from [1] and the wave function spatial overlapping parameters introduced by ref. [2]. In particular the same method of ref. [3] will be used but in addition the $\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$ branching ratios are fitted according to the prescriptions from [4]. This method is chosen because it relates our measurement of $Br(\phi \to \eta'\gamma)/Br(\phi \to \eta\gamma)$ [5] to the η' gluonium content and the η, η' mixing angle. The η and η' mixing angle and the presence of a gluonium component in the η'-meson have been mostly investigated in the past, but are still without a definitive conclusion [6]. Following the approach from [1,3] the η and η' wave functions can be decomposed in three terms: the u, d quark wave function $|q\bar{q}\rangle = \frac{1}{\sqrt{2}}(|u\bar{u}\rangle + |d\bar{d}\rangle)$, the strange component $|s\bar{s}\rangle$ and the $|glue\rangle$. The wave functions are written as follows:

$$\begin{aligned}|\eta'\rangle &= \cos(\varphi_G)\sin(\varphi_P)|q\bar{q}\rangle + \cos(\varphi_G)\cos(\varphi_P)|s\bar{s}\rangle \\ &\quad + \sin(\varphi_G)|glue\rangle \\ |\eta\rangle &= \cos(\varphi_P)|q\bar{q}\rangle - \sin(\varphi_P)|s\bar{s}\rangle,\end{aligned}$$

where φ_P is the η, η' mixing angle and $Z_G^2 = \sin^2\phi_G$ the gluon contribution. The ratio of the two branching ratios: $R_{\phi(1020)} = Br(\phi(1020) \to \eta'\gamma)/Br(\phi(1020) \to \eta\gamma)$ is related to this decomposition by the formula

$$R_{\phi(1020)} = \cot^2(\varphi_P)\cos^2(\varphi_G) \times \left(1 - \frac{m_s}{\bar{m}}\frac{Z_{NS}}{Z_S}\frac{\tan\varphi_V}{\sin 2\varphi_P}\right)^2 \left(\frac{p_{\eta'}}{p_\eta}\right)^3. \quad (1)$$

In this formula $p_{\eta'}$ and p_η are the momenta of the η'- and η-meson, respectively, $m_s/\bar{m} = 2m_s/(m_u + m_d)$ is the constituent quark masses ratio, Z_{NS} describes the spatial wave function overlapping between the $q\bar{q}$ component of the ω-meson and η-meson, and Z_S the one between the $s\bar{s}$ component of the η- and $\phi(1020)$-meson, ϕ_V is the ω,

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$\phi(1020)$ mixing angle. The parameters Z_S, Z_{NS}, ϕ_V and $m_s/\bar{m}$ are taken from [7] in which the $Br(\phi(1020) \to \eta'\gamma)$ and $Br(\phi(1020) \to \eta\gamma)$ are fitted together with other $V \to P\gamma$ decays (V indicates the vector mesons ρ, ω, $\phi(1020)$ and P the pseudoscalars π^0, η, η').

As in the KLOE [8] paper [5] we fit the ratio $R_{\phi(1020)}$ from the KLOE measurement

$$R_{\phi(1020)} = \frac{Br(\phi(1020) \to \eta'\gamma)}{Br(\phi(1020) \to \eta\gamma)} = 4.77 \pm 0.09_{\text{stat}} \pm 0.19_{\text{syst}} \times 10^{-3}$$

together with the available data [9] on $\Gamma(\eta' \to \gamma\gamma)/\Gamma(\pi^0 \to \gamma\gamma)$, $\Gamma(\eta' \to \rho\gamma)/\Gamma(\omega \to \pi^0\gamma)$ and $\Gamma(\eta' \to \omega\gamma)/\Gamma(\omega \to \pi^0\gamma)$. The dependence of these ratios on the mixing angle φ_P and the gluonium content ϕ_G is given by the following equations:

$$\frac{\Gamma(\eta' \to \gamma\gamma)}{\Gamma(\pi^0 \to \gamma\gamma)} = \frac{1}{9}\left(\frac{m_{\eta'}}{m_{\pi^0}}\right)^3 \times \left(5\cos\phi_G \sin\varphi_P + \sqrt{2}\frac{f_q}{f_s}\cos\phi_G\cos\varphi_P\right)^2, \quad (2)$$

$$\frac{\Gamma(\eta' \to \rho\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = 3\frac{Z_{NS}}{\cos(\phi_V)}\left(\frac{m_{\eta'}^2 - m_\rho^2}{m_\omega^2 - m_\pi^2}\cdot\frac{m_\omega}{m_{\eta'}}\right)X_{\eta'}^2, \quad (3)$$

$$\frac{\Gamma(\eta' \to \omega\gamma)}{\Gamma(\omega \to \pi^0\gamma)} = \frac{1}{3}\left(\frac{m_{\eta'}^2 - m_\omega^2}{m_\omega^2 - m_\pi^2}\cdot\frac{m_\omega}{m_{\eta'}}\right)^3 \times \left[Z_{NS}X_{\eta'} + 2\frac{m_s}{\bar{m}}Z_S \cdot \tan\phi_V Y_{\eta'}\right]^2. \quad (4)$$

Using the value of Z_{NS} and Z_S from [7], we obtain $\varphi_P = (39.7 \pm 0.7)^\circ$ and $Z_G^2 = \sin^2\varphi_G = 0.14 \pm 0.04$, $P(\chi^2) = 49\%$. Imposing $\varphi_G = 0$ the χ^2 probability of the fit decreases to 1%. The ratio of the Γ's is obtained using the branching fractions of the decay and the total decay widths Γ_ω, Γ_{π^0} from the PDG 2006 [9]. All the correlations amongst the measurements of the several branching ratios are taken into account. The correlations are due to the choice of normalising all decay widths to the $\Gamma(\omega \to \pi^0\gamma)$ and to the use of a constrained fit technique in the PDG 2006 in order to obtain more accurate estimates.

The parameter $m_s/\bar{m}$ is determined mainly by $K^{*+} \to K^+\gamma$ while ϕ_V is given by the $V \to \pi^0\gamma$ transitions, giving negligible correlations to the φ_P and Z_G^2 parameters. On the other hand, the parameters Z_S, Z_{NS} are strongly correlated to the mixing angle parameter, φ_P, in eq. (1). The constraint $\Gamma(\eta' \to \gamma\gamma)/\Gamma(\pi^0 \to \gamma\gamma)$ is, instead, independent of the parameters Z_{NS} and Z_S.

In ref. [3] a similar procedure to the one of [7] was followed taking into account also the possibility of having a gluonium content. They find $Z_G^2 = 0.04 \pm 0.09$ that deviates of 1 σ from our result but with a larger error.

In [3] and [10] this difference was attributed to the use of overlapping parameters obtained by a fit which assumes no gluonium content. In order to check out this possibility, we have performed several tests on the fit procedure. We first performed a new fit using the overlapping parameter Z_S and Z_{NS} extracted by the fit in ref. [3], where the gluonium content was left free, together with all the other parameters: $Z_{NS} = 0.86 \pm 0.03$, $Z_S = 0.79 \pm 0.05$, $\phi_V = (3.2 \pm 0.1)^\circ$, $\frac{m_s}{\bar{m}} = 1.24 \pm 0.07$. We obtained a result in perfect agreement with our previous determination: the errors remain unchanged while the central values move to $\varphi_P = 40.1$, $Z_G^2 = 0.12$.

Table 1. Summary of the results obtained using new values for Z_{NS} and Z_S from [3].

Used inputs	φ_P	Z_G^2
1, 2, 3, 4 $\Gamma(\omega \to \pi^0\gamma)$ from PDG 2006 [9]	$(40.1 \pm 0.7)^\circ$	0.12 ± 0.04
1, 3, 4 $\Gamma(\omega \to \pi^0\gamma)$ from PDG 2006 [9]	$(40.4 \pm 0.9)^\circ$	0.12 ± 0.05
1, 2, 3, 4 $\Gamma(\omega \to \pi^0\gamma)$ from KLOE [11]	$(40.0 \pm 0.7)^\circ$	0.13 ± 0.04

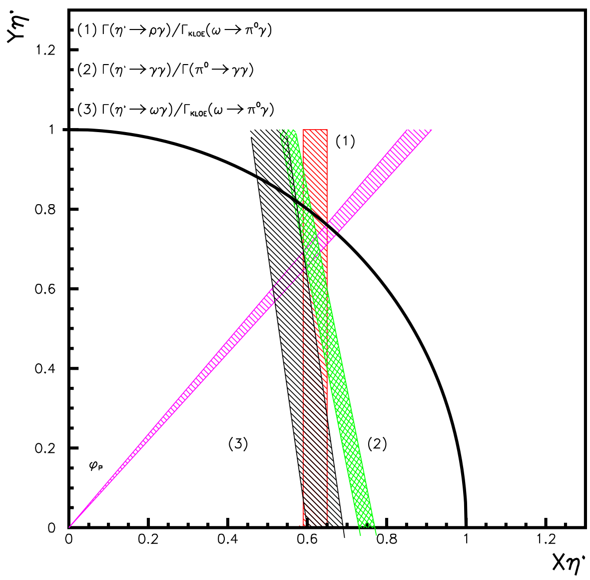

Fig. 1. 68% C.L. region in the plane ($X_{\eta'} = \cos(\varphi_G)\sin(\varphi_P)$, $Y_{\eta'} = \cos(\varphi_G)\cos(\varphi_P)$) for diffrent decay width ratios.

The value of the fit has been also repeated for different values of Z_{NS} and Z_S in the range 0.5–1.3, and the resulting Z_G^2 varied between 0.07 and 0.18, showing small sensitivity to the used parameters Z_{NS} and Z_S that cannot cause the different result obtained by ref. [3]. Excluding the $P \to \gamma\gamma$ constraint from the fit we obtain $\varphi_P = (40.4 \pm 0.9)^\circ$ and $Z_G^2 = 0.12 \pm 0.05$, showing that this constraint improves the sensitivity for the gluonium content. All results are summarized in table 1.

A global fit to all the $V \to P\gamma$ ratios of the branching fractions is in progress. This will allow the overlapping parameters to be left free as in the approach of ref. [3], that is quite different than ours in both fit procedure and input values.

2 New value using KLOE $\Gamma(\omega \to \pi^0\gamma)$ measurement

We have recently published [11] a new preliminary measurement of the $Br(\omega \to \pi^0\gamma) = (8.40 \pm 0.19)\%$. Using this value we obtain $Z_G^2 = 0.13 \pm 0.04$ and $\varphi_P = (40.0 \pm 0.7)^\circ$. The allowed regions in the plane ($X_{\eta'} = \cos(\varphi_G)\sin(\varphi_P)$, $Y_{\eta'} = \cos(\varphi_G)\cos(\varphi_P)$), corresponding to the constraints in eqs. (2)–(4) are shown in fig. 1. Theoretical parameters are taken from [7]. All the allowed regions do not overlap on the no-gluonium line $X_{\eta'}^2 + Y_{\eta'}^2 = 1$, suggesting that the no-gluonium picture is wrong.

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