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Decays of The Pseudoscalar Glueball into Scalar and Pseudoscalar Mesons

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eQCD 2012, Peniche, May 8. 2012

Introduction

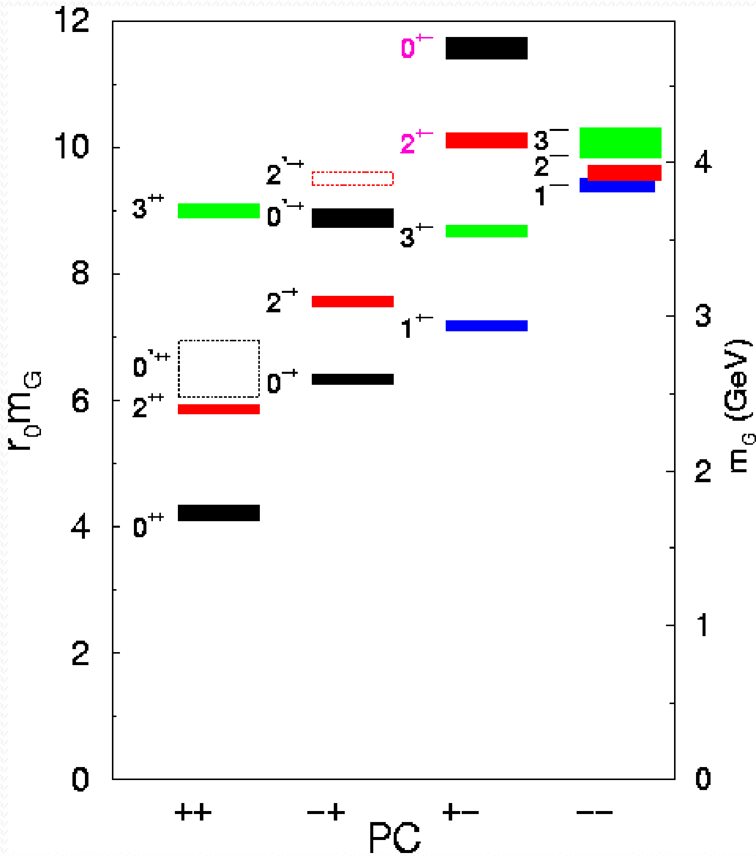
- Quantum chromodynamic (QCD) is the theory of the strong interactions.
- QCD predicts colorless bound states of the gluons. (the glueballs).
- A glueball is a hypothetical particle. It consists of solely gluon particles, without valence quarks.
- Important for phenomenology.
- Glueballs are a solid Lattice QCD prediction.

Lattice QCD calculations

[C. Morningstar and M. J. Peardon, AIP Conf. Proc. 688, 220 (2004)

[arXiv:nucl-th/0309068]]

[Y. Chen *et al*.**,** ***Phys. Rev.*** **D 73, 014516 (2006)]**



There is a pseudoscalar glueball, with the mass around 2.5 GeV predicted by lattice QCD calculation.

$$\breve{G} \equiv |gg\rangle \qquad J^{PC} = 0^{-+}$$

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- Two experiments related to our work :

1. PANDA able to study energies above 2.5 GeV.
2. BESIII found a pseudoscalar glueball candidate with a mass of about 2.3 GeV.

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The Effective Lagrangian

An effective interacting Lagrangian with the glueball chiral symmetry $L_{\breve{G}}^{int} = ic_{\breve{G}\phi}\breve{G}\left[\det\Phi - \det\Phi^{\dagger}\right],$

where $c_{\breve{G}\phi}$ is a coupling constant and dimensionless , Ğ is pseduoscalar glueball and $\Phi = (S^a + i P^a)t^a$ is a multiplet of the scalar and pseudoscalar quark-antiquark states and are the generators of the group $U(N_f)$

$\Phi \rightarrow U_L \Phi U_R^{\dagger}$, $SU_R(3)\times SU_L(3)$ but breaks $U_A(1)$

Consider the case of $N_f = 3$ and the explicit representation of the scalar and pseudoscalar mesons.

$$\Phi = \frac{1}{\sqrt{2}}\begin{pmatrix} \frac{\sigma_N + a_0^0 + i(\eta_N + \pi^0)}{\sqrt{2}} & a_0^+ + i\pi^+ & K_S^+ + iK^+ \\ a + i\pi^- & \frac{\sigma_N - a_0^0 + i(\eta_N - \pi^0)}{\sqrt{2}} & K_S^0 + iK^0 \\ K_S^- + iK^- & \bar{K}_S^0 + i\bar{K}^0 & \sigma_S + i\eta_S \end{pmatrix}$$

[D. Parganlija, F. Giacosa, D. H. Rischke, P. Kovacs, and G. Wolf, Int. J. Mod. Phys. A 26 607-609 (2011) [arXiv 1009.2250 [hep-ph]].

The assignment of the quark-antiquark fields is as follows:
(i) In the pseudoscalar fields $\vec{\pi}$ (pion) and K(kaons).

The bare fields $\eta_N = |\bar{u}u + \bar{d}d\rangle / \sqrt{2}$ *and* $\eta_S = |\bar{s}s\rangle$ are the non-strange and strange mixing contributions of the physical state η and η'

$$\eta = \eta_N \cos\phi + \eta_S \sin\phi$$

$$\eta' = -\eta_N \sin\phi + \eta_S \cos\phi$$

$$where \quad \phi \simeq 36^o \quad is\ the\ mixing\ angle$$

[K. Nakamura et al. (Particle Data Group), J. Phys. G 37, 075021 (2010).]

(ii) In the scalar sector we assign the field $\overrightarrow{a_0}$ to the physical isotriplete state a_0 (1450) and the kaons fields K_S to the physical isodoublt state K_0^* (1430).

Finally , the non-strange and strange bare fields

$$\sigma_N = \left| \bar{u}u + \bar{d}d \right\rangle / \sqrt{2} \quad and \quad \sigma_S = \left| \bar{s}s \right\rangle$$

to the physical I = 0 resonances f_0 (1370) and f_0(1710).
Mixing neglected here of σ_N , σ_S

Shifting the fields $\sigma_N \to \phi_N + \sigma_N$ with

$$\phi_N = Z_\pi f_\pi \ , \quad \sigma_S \to \phi_S + \sigma_S \ , \qquad \phi_S = Z_K f_K / \sqrt{2}$$

$$Z_\pi = 1.66 \ , \quad Z_k = 1.39$$ [D. Parganlija thesis]

η_N , η_S are unphysical , the value of mixing large.

η_N , η_S with $\breve{G}$ small mixing so neglected it.

$\eta\eta'$ is physical mixing because they have the same quantum number.

[D. Parganlija, F. Giacosa and D. H. Rischke, Phys. Rev. D 82, 054024 (2010) [arXiv:1003.4934 [hep-ph]].

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Results and Discussion

A. Scenario with $M_{\breve{G}} = 2.6\,GeV$ as a prediction for the PANDA experiment

In this scenario we set the bare mass of the pseudoscalar glueball $\breve{G} \equiv |gg\rangle$, $J^{PC} = 0^{-+}$ according to the lightest pseudoscalar-isoscalar glueball obtained from lattice QCD simulations.

This scenario is referring on the one hand to the future experiment PANDA and with lattice QCD predicted mass.

B. Scenario with $M_{\eta_{gg}} = 2.3\,GeV$ with respect to the BESIII experiment

The calculations in second scenario are implemented with respect to the results of the experiment BESIII, where the resonance $X(2370)$ was observed and therefore we used $M_{\eta_{gg}} = 2.3\,GeV$ as the physical mass of the pseudoscalar glueball $\eta_{gg} = |gg\rangle$

Results for A

Quantity	Value
$\Gamma_{\tilde{G}\to KK_S}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	5.37
$\Gamma_{\tilde{G}\to a_0\pi}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	5.10
$\Gamma_{\tilde{G}\to\eta\sigma_N}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	2.04
$\Gamma_{\tilde{G}\to\eta\sigma_S}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	1.22
$\Gamma_{\tilde{G}\to\eta'\sigma_N}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	1.67

Quantity	Value
$\Gamma_{\tilde{G}\to KK\eta}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	0.80
$\Gamma_{\tilde{G}\to KK\eta'}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	0.17
$\Gamma_{\tilde{G}\to\eta\eta\eta}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	0.23
$\Gamma_{\tilde{G}\to\eta\eta\eta'}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	0.02
$\Gamma_{\tilde{G}\to\eta\eta'\eta'}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	0.0003
$\Gamma_{\tilde{G}\to KK\pi}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	4.96
$\Gamma_{\tilde{G}\to\eta\pi\pi}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	1.34
$\Gamma_{\tilde{G}\to\eta'\pi\pi}/\Gamma_{\tilde{G}\to\pi^0K^-K^+}$	1.48

Results for B

Quantity	Value
$\Gamma_{\eta_{gg}\to KK_S}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	6.53
$\Gamma_{\eta_{gg}\to a_0\pi}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	6.70
$\Gamma_{\eta_{gg}\to\eta\sigma_N}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	2.52
$\Gamma_{\eta_{gg}\to\eta\sigma_S}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	0.61

Quantity	Value
$\Gamma_{\eta_{gg}\to KK\eta}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	0.66
$\Gamma_{\eta_{gg}\to KK\eta'}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	0.08
$\Gamma_{\eta_{gg}\to\eta\eta\eta}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	0.17
$\Gamma_{\eta_{gg}\to\eta\eta\eta'}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	0.01
$\Gamma_{\eta_{gg}\to KK\pi}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	4.95
$\Gamma_{\eta_{gg}\to\eta\pi\pi}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	1.45
$\Gamma_{\eta_{gg}\to\eta'\pi\pi}/\Gamma_{\eta_{gg}\to\pi^0K^-K^+}$	1.38

Decay channel of the pseudoscalar glueball

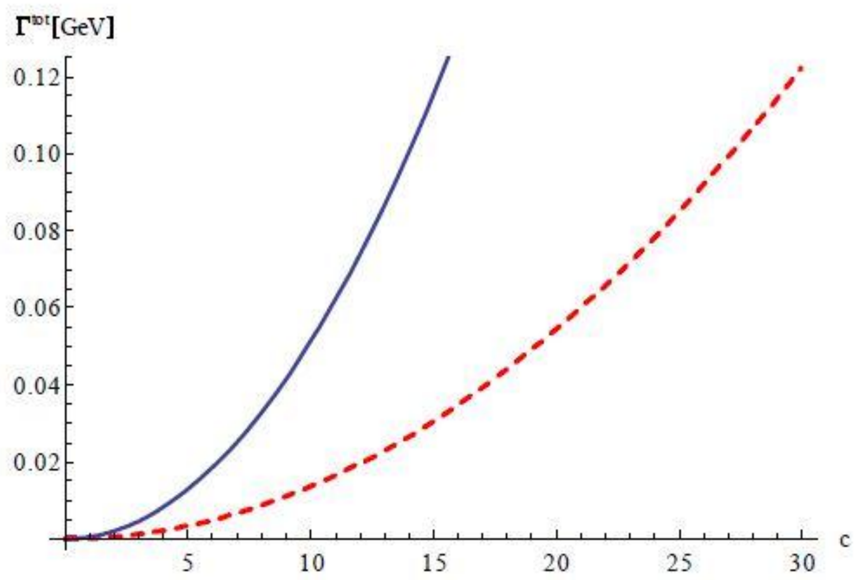

FIG. 1: BLUE LINE: Total decay width of the pseudoscalar glueball with the bare mass $M_{\tilde{G}} = 2.6\ GeV$
b) RED DASHED LINE: Total decay width of the pseudoscalar glueball with the physical mass

$$M_{\eta_{gg}} = 2.3\ GeV$$

Conclusions and Outlook

* Presentation of a globally chirally invariant effective lagrangian with scalar and pseudoscalar quark- antiquark states and a pseudoscalar glueball state.

* Study in the case of $N_f = 3$ the decays of the pseudoscalar glueball with a mass above 2 GeV.

* Consideration two scenarios regarding the mass of the pseudoscalar glueball.

*The mixing between the pseudoscalar glueball and the pseudoscalar mesons is small.

Thank You