Gluonium States and $\eta_c \rightarrow \gamma X$.

S. Minami

Department of Physics, Osaka City University - Sumiyoshi-ku, Osaka 558, Japan

(ricevuto il 29 Agosto 1983)

PACS. 13.90. – Other topics in specific reactions and phenomenology of elementary particles.

Summary. - The effects of gluonium states on $\eta_c(2980) \rightarrow \gamma X$ are discussed. In order to examine the properties of vector glueball, measurements of the inclusive $\gamma$ spectrum in $\eta_c \rightarrow \gamma X$ or those of the $\rho \pi(\bar{K}K^*)$ mass distributions in $\eta_c \rightarrow \gamma \rho \pi(\eta_c \rightarrow \gamma \bar{K}K^*)$ are suggested.

A vector glueball $\sigma$ with $M = (1.4-1.8) \text{ GeV}$ corresponding to a pomeron daughter was first postulated by Freund and Nambu (1). They emphasized that the breaking of the OZI-rule results from the mixing of the $\omega$, $\phi$ and $J/\psi$ mesons with the $\sigma$. Hou and Soni (2) have proposed that the observed enhancement of the $J/\psi \rightarrow \rho \pi$ and $J/\psi \rightarrow \bar{K}K^*$ decay modes is being caused by a quantum-mechanical mixing of the $J/\psi$ with a vector glueball whose mass is about 2.4 GeV.

In a previous paper (3) we have estimated the mass of vector glueball $\sigma$ and studied the properties of the $\omega'$ and $\omega''$ on the basis of a model in which the $\omega'$ is an admixture of a $q\bar{q}$ state and the $\sigma$, where the $\omega'$ and $\omega''$ are given by

(1) \[ \omega' = \cos \theta |q\bar{q}\rangle + \sin \theta |\sigma\rangle, \]

and

(2) \[ \omega'' = -\sin \theta |q\bar{q}\rangle + \cos \theta |\sigma\rangle. \]

As a result, we have obtained

(3) \[ M(\sigma) \approx M(\omega') \approx M(\omega'') \approx 1.57 \text{ GeV} \]

for the masses of the vector mesons with $I = 0$.

This is consistent with the predictions in ref. (1), but there is a considerable difference between the estimated masses of the O in ref. (2) and (3). It is necessary to discuss which model is the most promising among them, on the basis of considerations about the glueball-favoured channels. In this paper we study the effects of glueballs on the radiative decays $\gamma \rightarrow \gamma X$.

Some of the points we wish to emphasize are the following:

i) measurements of the inclusive $\gamma$ spectrum in $\gamma_c(2980) \rightarrow \gamma X$ enable us to determine which model should be adopted;

ii) the exclusive radiative decay $\gamma_c \rightarrow \gamma\rho\pi$ or $\gamma_c \rightarrow \gamma KK^*$ mainly proceeds via the intermediate state $\gamma + O$, while $\gamma_c \rightarrow \gamma KK$ or $\gamma_c \rightarrow \gamma\pi\pi$ has nothing to do with the O, since the process $O \rightarrow KK$ ($\pi\pi$) is forbidden;

iii) there is a possibility that the radiative decay $\gamma_c \rightarrow \gamma KK$ or $\gamma_c \rightarrow \gamma\pi\pi$ takes place through the $O \rightarrow$ glueball $G$ with $M \simeq 1440$ MeV, that is $\gamma_c \rightarrow G \rightarrow \gamma KK$ ($\gamma\pi\pi$).

First we consider the reactions by which the existence of the O can be confirmed and the correct value of its mass is given. In the model of ref. (1) or (2), hadronic decays of $J/\psi$ mainly go via the sequence

$$J/\psi \rightarrow O \rightarrow \rho\pi,$$

$$\gamma \rightarrow O \rightarrow \gamma KK^*.$$

Their decays in our scheme (3) also take place through the processes

$$J/\psi \rightarrow O \rightarrow \omega' \rightarrow KK^*,$$

$$\gamma \rightarrow O \rightarrow \omega' \rightarrow KK^*(\rho\pi).$$

Since not only the O, but also the $\omega$, $\rho$, $\omega'$ or $\omega_0$ in the intermediate states cannot be real, it is impossible to get directly any information about the mass of the O from the data for $J/\psi \rightarrow \rho\pi(KK^*)$. Here let us recollect the fact that the glueballs which are even under charge conjugation $C$ have been investigated extensively in the radiative decays ($4$) $J/\psi \rightarrow \gamma X$. Then we may say as follows: It is the process $\eta_c(2980) \rightarrow \gamma X$ that can be regarded as a glueball-favoured channel for the odd-$C$ glueballs such as the O. In what follows we study the radiative decays of the $\eta_c(2980)$.

In our scheme (3), the exclusive radiative decay $\eta_c \rightarrow \gamma\rho\pi$ or $\eta_c \rightarrow \gamma KK^*$ proceeds via the following sequence (see fig. 1a)). First the $\eta_c$ emits a photon and changes into a virtual $J/\psi$ state. Next the $J/\psi$ transits to a vector glueball $O$, and $\omega'$ or $\omega_0$ is produced through the $|O\rangle$ state. Finally the $\omega'$ or $\omega'_{0}$ decays into $\rho\pi$ or $KK^*$. Therefore, the mass spectrum of the $\rho\pi(KK^*)$ in $\eta_c \rightarrow \gamma\rho\pi(\gamma KK^*)$ ought to have a pronounced peak at about 1.57 GeV. In the HS model (2), on the other hand, there must be a peak around 2.4 GeV in the $\rho\pi(KK^*)$ mass distributions.

The properties of the O should be reflected on the $\gamma$ spectrum in the inclusive radiative decays of the $\eta_c$. That is, the $\gamma$ spectrum in $\eta_c \rightarrow \gamma X$ has an enhancement at about 1076 MeV (524 MeV) when the mass of the O is equal to 1.57 GeV (2.4 GeV). We want to emphasize that measurements of the $\rho\pi(KK^*)$ mass spectrum or those