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THE 1500-1700 MeV MASS REGION AND GLUEBALL SEARCHES IN TWO-PHOTON COLLISIONS WITH THE L3 DETECTOR AT LEP

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ABSTRACT

The $\pi^+\pi^-\pi^0$ and the $K^0_sK^0_s$ final states in two-photon collisions are studied with the L3 detector at LEP. The $\pi^+\pi^-\pi^0$ mass spectrum is dominated by the formation of the $a_2(1320)$ tensor meson in the helicity two state. Evidence is observed for the formation of its radial recurrence at 1750 MeV. The $K^0_sK^0_s$ mass spectrum is dominated by the formation of the $f_2'(1525)$ tensor meson in the helicity two state. Clear evidence for destructive f_2-a_2 interference is observed. An enhancement of about 7 standard deviations is present around 1750 MeV. The study of the angular distribution favours a spin zero assignment over spin two, supporting the glueball interpretation of the $f_0(1500)$ state. No signal is present in the region around 2.2 GeV. An upper limit for the two-photon partial width of the $\xi(2220)$ glueball candidate is derived.

1 Introduction

The 1500-1700 MeV region is very important in hadron spectroscopy since the lightest glueball is expected to be found in this mass range in which several mesons have been observed. Some radial recurrences of the ground state mesons are also predicted in this region. The search for the lightest glueball is complicated by the fact that it is expected to have $J^{PC}=0^{++}$ and then it can mix with nearby states of the scalar nonet. Since gluons do not couple to photons, the two photon width of a state with high gluonic content is expected to be very small. A state that can be formed in a gluon rich environment but not in two photon fusion is a good candidate for a glueball. Two-photon interactions play therefore a crucial role in glueball searches.

Two-photon collisions at electron positron storage rings are a good laboratory to investigate the properties of meson resonances in a low background environment. In the reaction $e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-R$ the outgoing electron and positron are usually scattered at very small angles and are not detected. The two photons are then quasi real and the resonance R must be a neutral unflavoured meson with C=1 and J$\neq$1. The decay final state constrains the J^{PC} quantum numbers of the resonance. Considering J$\leq$2, J^{PC} must be 0^{++}, 2^{++} or 2^{-+} for the $\pi^+\pi^-\pi^0$ final state and 0^{++} or 2^{++} for the $K^0_sK^0_s$ final state. The cross section for this process is given by the convolution of the QED calculable luminosity function $\mathcal{L}$, giving the flux of the photons, with the two-photon cross section $\sigma(\gamma\gamma \to R)$ that can be expressed by a Breit-Wigner function. This leads to the proportionality relation $\sigma_T(e^+e^- \to e^+e^-R) = \mathcal{K}\;\Gamma_{\gamma\gamma}(R)$ that allows to extract the two-photon width from the cross section. Since $\mathcal{L}$ increases with the beam energy, the continuously increasing performance of the LEP machine gives the opportunity to investigate more and more accurately the formation of meson resonances.

2 The $\pi^+\pi^-\pi^0$ final state

A study of the reaction $\gamma\gamma \to \pi^+\pi^-\pi^0$ [1] is performed using 140 pb^{-1} of data collected at $\sqrt{s} \simeq 91$ GeV. Events are selected by requiring two oppositely charged tracks, two isolated electromagnetic clusters with $m_{\gamma\gamma}$ between 105 and 165 MeV and $|\vec{p_T}(\pi^+\pi^-\pi^0)|^2 < 0.0015$ GeV^2. The mass spectrum (fig. 1(a) and table 1) is dominated by the formation of the $a_2(1320)$ tensor meson. A clear enhancement is visible around 1750 MeV where the study of the total transverse momentum distribution shows evidence for an exclusive process. The data sample is therefore divided into two mass ranges: form 1 up to 1.55 GeV, in order to study the a_2, and from 1.55 up to 2.1 GeV. The study of the angular distributions shows that the a_2 formation is dominated by a J^{PC}=2^{++} helicity 2 wave. The helicity 2 fraction is

Table 1: Results for the $\pi^+\pi^-\pi^0$ final state.

	$a_2(1320)$	1750 MeV Region
Mass (MeV)	$1323 \pm 4 \pm 3$	$1752 \pm 21 \pm 4$
Width (MeV)	$105 \pm 10 \pm 11$	$150 \pm 110 \pm 34$

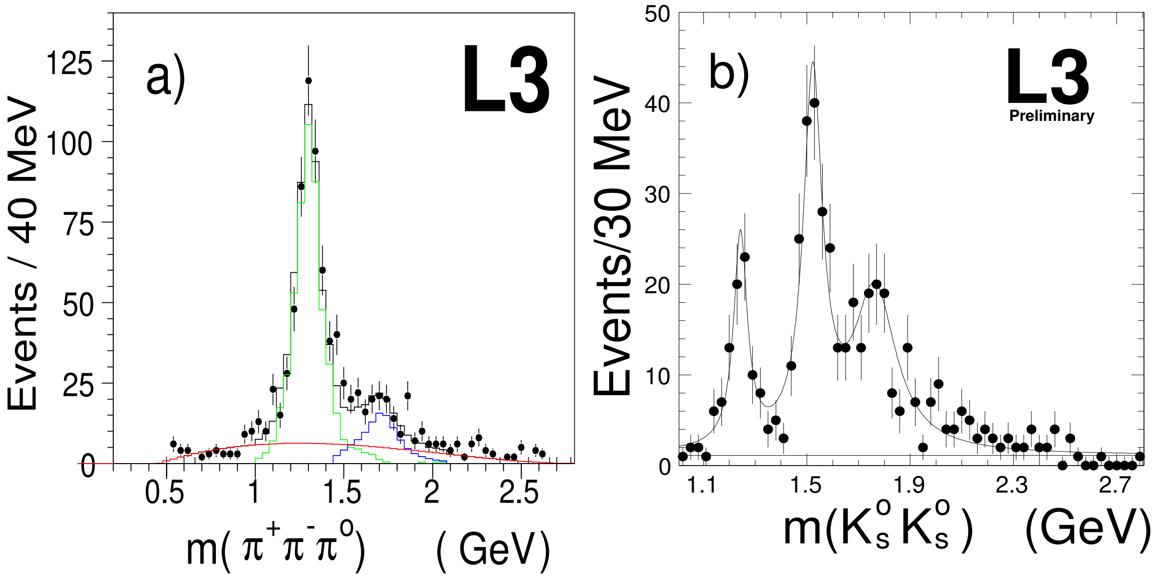

Figure 1: *The* $\pi^+\pi^-\pi^0$ *(a) and the* $K_s^0 K_s^0$ *(b) mass spectra.*

measured to be 0.92±0.05±0.05. The radiative width is found to be $\Gamma_{\gamma\gamma}(\mathrm{a}_2) = 0.98 \pm 0.05 \pm 0.09$ keV. A spin-parity analysis in the high mass region shows that also this region is dominated by a J^{PC}=2^{++} helicity 2 wave, confirming the observation of [2] and in contradiction with [3]. This can be interpreted as the formation of a radial recurrence of the a_2 for which $\Gamma_{\gamma\gamma}(\mathrm{a}_2'(1765)) \times \mathrm{BR}(\pi^+\pi^-\pi^0) = 0.29 \pm 0.04 \pm 0.02$ keV in agreement with the theoretical predictions [4]. The J^{PC}=2^{-+} wave contribution is found compatible with zero.

3 The $\mathrm{K}_s^0\mathrm{K}_s^0$ final state

A study of the reaction $\gamma\gamma \to \mathrm{K}_s^0\mathrm{K}_s^0$ [5] is performed by selecting four charged track events with $|\vec{p_T}(\pi^+\pi^-\pi^+\pi^-)|^2 < 0.1$ GeV^2. Within these events two K_S^0 candidates are searched for by secondary vertex reconstruction. In the data collected at $\sqrt{s}$ = 91 GeV ($\mathcal{L}$=143 pb^{-1}), at $\sqrt{s}$ = 183 GeV ($\mathcal{L}$=52 pb^{-1}) and at $\sqrt{s}$ = 189 GeV ($\mathcal{L}$=172 pb^{-1}), 499 events are selected. The mass spectrum (fig. 1(b) and table 2) is dominated by the formation of the $\mathrm{f}_2'(1525)$ tensor meson. The $\mathrm{f}_2(1270)-\mathrm{a}_2(1320)$

Table 2: Results of the unbinned maximum likelihood fit with three Breit-Wigner functions and a constant on the $\mathrm{K}_S^0\mathrm{K}_S^0$ mass spectrum.

	f_2-a_2	$\mathrm{f}_2'(1525)$	1750 MeV Region
Mass (MeV)	—	1523 ± 8	1765 ± 22
Width (MeV)	—	89 ± 37	200 ± 50
Number of events	75 ± 15	184 ± 27	171 ± 26

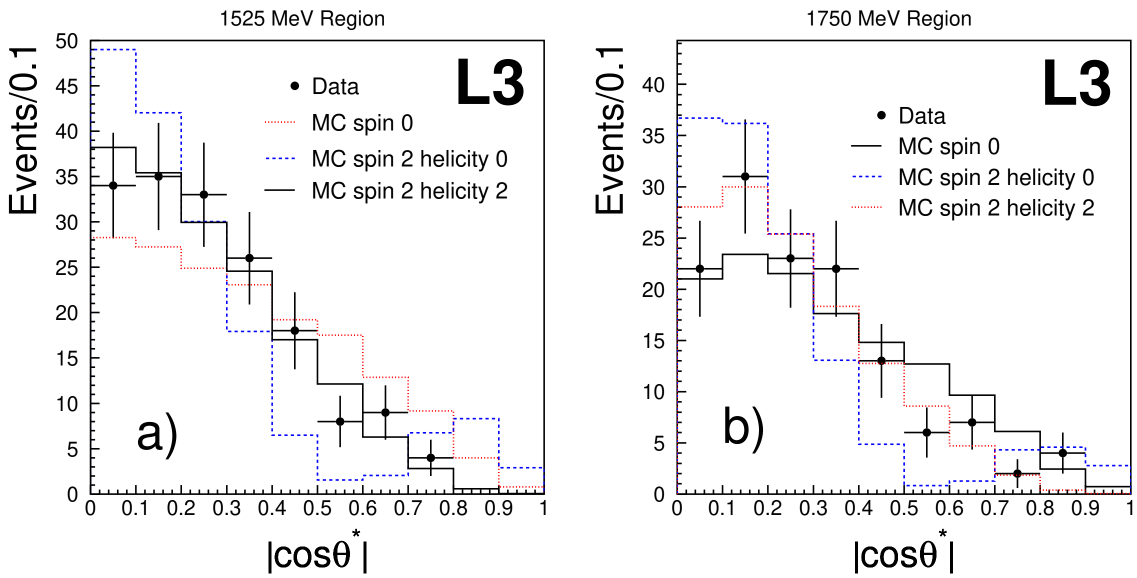

Figure 2: *The $K^0_S K^0_S$ polar angular distribution compared with the Monte Carlo distributions for the hypothesis of a pure spin two helicity-zero, spin two helicity-two and spin zero contribution for the $f_2'(1525)$ (a) and for the 1750 MeV region (b).*

region shows the destructive $\mathrm{f}_2-\mathrm{a}_2$ interference in the $\mathrm{K}^0_S\mathrm{K}^0_S$ final state in agreement with the theoretical predictions [6]. A clear enhancement is visible in the 1750 MeV region. No excess is present around 2230 MeV.

3.1 The $\mathrm{f}_2'(1525)$ tensor meson

Two quasi real photons can form a tensor meson in the helicity zero or helicity two state. The angular distribution and the detection efficiency are very different in the two cases. In order to determine the helicity state, a study of the angular distribution of the K^0_S in the two-photon centre of mass is performed (fig. 2(a)). The χ^2 values for nine degrees of freedom are 93 for spin two helicity-zero, 4.6 for spin two helicity-two and 21 for spin zero. Thus pure helicity-zero is excluded and helicity-two is largely dominant, in agreement with the theoretical predictions [7]. Combining the results for the various beam energies, the published value [5] $\Gamma_{\gamma\gamma}(\mathrm{f}_2')\times\mathrm{Br}(\mathrm{f}_2' \to \mathrm{K\bar{K}}) = (0.093 \pm 0.018 \pm 0.022)$ keV is confirmed, under the hypothesis of a pure helicity-two formation.

3.2 The 1750 MeV region

The enhancement around 1750 MeV is very interesting for the search for the ground state 0^{++} glueball. The identification of the 0^{++} meson nonet is very difficult due to the large number of states observed in the 1500-1700 MeV region [10]. In the scenario presented in [8], the $f_0(1500)$ is compatible with the ground state scalar glueball expected around 1500 MeV. This hypothesis includes the prediction of a further scalar state, the $f_0'(1500\text{-}1800)$, mainly composed by s quarks. This state must couple strongly with $K\bar{K}$ and could be formed in two-photon fusion. Like the $a_2'(1765)$, the enhancement around 1750 MeV may also be a radially excited $f_2'(1525)$, according to theoretical predictions [4]. In order to investigate the spin of the 1750 MeV region, the angular distribution of the K^0_S in the two-photon centre of mass is studied (fig. 2(b)). The χ^2 values for nine degrees of freedom are 89 for spin two helicity-zero, 38 for spin two helicity-two and 12 for spin zero. The spin zero assignment is therefore favoured.

3.3 The 2230 MeV region

The BES Collaboration confirmed the observation of a resonance, the $\xi(2230)$ [9], produced in radiative decays of the J/ψ particle. Due to its narrow width and its production in a gluon rich environment, this state is considered a candidate for the tensor glueball, consistent with the lattice QCD predictions. For this reason it is important to make a quantitative statement about the fact that the $K^0_sK^0_s$ mass spectrum (fig. 1(b)) shows no evidence for its formation. A Monte Carlo simulation is used to determine the detection efficiency for the $\xi(2230)$ using the values for the mass and the width determined by combining the results by Mark III and BES. The upper limit $\Gamma_{\gamma\gamma}(\xi(2230))\times\mathrm{Br}(\xi(2230) \to K^0_SK^0_S) < 1.5$ eV at 95% C.L. is obtained under the hypothesis of a pure helicity-two state, using the standard method [10] for extracting an upper limit for a Poisson distribution with background. Results from different beam energies are combined using a Monte Carlo method. Combining the results reported by BES and Mark III for the $\Gamma(J/\psi \to \gamma\xi)\times\mathrm{Br}(\xi \to K^0_SK^0_S)$ and our upper limit on $\Gamma(\xi \to \gamma\gamma)\times\mathrm{Br}(\xi \to K^0_SK^0_S)$, we obtain a lower limit on the stickiness [11] $S_{\xi(2230)} > 68$ at 95% C.L. Errors are taken into account by a Monte Carlo calculation. This very high value supports the glueball interpretation of the $\xi(2230)$.

4 Conclusions

Two-photon collisions play a crucial role in hadron spectroscopy since they offer a clean experimental environment and they are a powerful tool to distinguish glueballs from quarkonia. The $\pi^+\pi^-\pi^0$ and the $K^0_sK^0_s$ final states allow the study of the well known $a_2(1320)$ and $f_2'(1525)$ tensor mesons and reveal new states at higher masses. The $\pi^+\pi^-\pi^0$ shows evidence for the formation of the radially excited tensor meson

$a_2'(1765)$. The $K_s^0K_s^0$ shows the formation of a state around 1750 MeV whose identification is very important for glueball searches. Data favour a spin zero assignment but spin two cannot be excluded with the present statistics. The formation of the $\xi(2230)$ tensor glueball candidate can be excluded. The L3 detector at LEP II will take data at beam energies around 100 GeV for two more years. This large amount of data will bring a significant contribution to hadron spectroscopy and glueball searches.

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