ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ СО АН СССР

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НОВОСИБИРСК

RESULTS OF MD-1 DETECTOR ON THE SEARCH OF ξ(2.2) IN THE DECAYS $\Upsilon \to \gamma K^+K^-$ AND $\Upsilon \to \gamma\varphi\varphi$.*

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Abstract

The results of an experiment on the search of ξ (2.2) in the decays $\Upsilon \to \gamma\xi$(2.2) are presented. The experiment was carried out with the detector MD-1 at the collider VEPP-4. Upper limits $B(\Upsilon \to \gamma\xi)B(\xi \to K^+K^-) < 2 \cdot 10^{-4}$ and $B(\Upsilon \to \gamma\xi)$ $B(\xi \to \varphi\varphi) < 3 \cdot 10^{-3}$ are obtained at 90% C.L.

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1. INTRODUCTION

The resonance ξ (2.2) was discovered at the detector MARK III in 1983 in the radiative decays of J/ψ to K^+K^- /1/. Later MARK III confirmed its result with greater statistics observing ξ in the decays to K^+K^- and K_sK_s /2/. Analysis of the decay $\xi \to K_sK_s$, carried out at this detector, gives for the resonance the quantum numbers $J = 2^{++}$, although 4^{++} is not excluded /3/. Radiative decays of J/ψ were also investigated at the detector DM2. The decays $J/\psi \to \gamma\xi$, $\xi \to K^+K^-$, K_sK_s were not confirmed /4/. At this detector in the decays $J/\psi \to \gamma\varphi\varphi$ a narrow state was found in the $\varphi\varphi$ -system with a mass of 2.2 GeV/c^2 and $J = 0^-$, although $2^{\pm}$ is not excluded /5/. In the reaction $\pi^-p \to \eta\eta' + n$, that was investigated at the detectors GAMS-2000 in IHEP and GAMS-4000 in CERN, a narrow resonance was discovered in the $\eta\eta'$ system with a mass of 2.22 GeV/c^2 and $J \geq 2$ /6/. In Serpukhov at the magnetic spectrometer in the reaction $\pi^-p \to K_sK_sn$ a state was found with a mass of 2.23 GeV/c^2 and $J = 2^{++}$ in K_sK_s system /7/. The results of investigation of the reactions $K^-p \to \Lambda K^+K^-$ and $K^-p \to \Lambda K_sK_s$ with LASS spectrometer give evidence on the existence of ξ in the system K^+K^- and K_sK_s with $J \geq 2^+$, preferrably 4^+ /8/. It seems that the same particle is observed in all these experiments.

The discovery of ξ gave rise to its search in radiative decays of the Υ -meson. The upper limits for the decays $\Upsilon \to \gamma\xi$, $\xi \to K^+K^-$ were obtained with the detectors CLEO, CUSB and MD-1 /9-12/. The search for ξ in the inclusive channel $\Upsilon \to \gamma\xi$ was performed at the detectors CUSB and CRYSTAL BALL/13,14/

For the explanation of ξ (2.2) nature various theoretical hypotheses were suggested: Higgs boson, gluonium, hybrid state, meson with high spin. The hypothesis that ξ is a Higgs boson seems to be ruled out. The nature of this resonance still remains to be not clear.

One should note that the data on the radiative decays of J/ψ and Υ give the restrictions on the existence of light Higgs bosons. The obtained limits do not yet reach the predictions of the standard model of electroweak interactions with one Higgs doublet. Predictions of models with a more rich

Higgs sector are not well determined and the available experiments on the radiative decays of J/ψ and Υ give the restrictions on the parameters of these models.

In this paper we present the results on the search of ξ in radiative decays of Υ-meson performed with the detector MD-1. The value of the upper limit for the decay probability $\Upsilon \to \gamma \xi$, $\xi \to K^+K^-$ confirms the preliminary result /12/ and is obtained by new data analysis. The routines of event simulation and reconstruction were improved. For the first time the upper limit for the decay probability of $\Upsilon \to \gamma \xi$, $\xi \to \varphi\varphi$ was obtained.

2. Experiment

The experiment was carried out with the detector MD-1 (fig. 1) /15/, that was installed at the storage ring VEPP-4. Magnetic field of the detector was perpendicular to the orbit plane and in this experiment was equal to 11.3 kG.

Charged particles were detected and there momenta were measured with 38 proportional chambers of the detector. Momentum of a charged particle was measured with an accuracy of $\sigma_p = 0.1 \cdot p^2$ (p in GeV/c) in the solid angle $0.6 \cdot 4\pi$. Outgoing direction of particle was measured in the solid angle $0.8 \cdot 4\pi$.

The photons were detected by a system of shower-range chambers consisting of 14 separate blocks. Every block contains 10 proportional chambers separated by the plates of stainless steel 13 mm thick. The accuracy of the angle measurement for the outgoing photon $\sigma_\theta = 2 \cdot 10^{-2}$ radian. For the photon energy of 4.5 GeV energy resolution $\sigma_E/E \sim 30\%$.

The detector includes 8 Cherenkov counters, covering a $0.6 \cdot 4\pi$ solid angle. A threshold value of the relativistic factor $\gamma = 5$, allowing kaon separation in the momentum region from 0.7 to 2.5 GeV/c.

Data have been taken from October 1983 till July 1984. Integrated luminosity is 6.5 pb^{-1} at the Υ-resonance and 2.7 pb^{-1} aside the resonance. The number of recorded events equals $1.5 \cdot 10^7$. The number of produced Υ-mesons equals 94000. The experiment consists of two cycles with the integrated luminosity 4.5 pb^{-1} and 4.7 pb^{-1} respectively, which

differ by trigger conditions.

3. Experimental data processing

The selection criteria were chosen on the base of the analysis of the detection efficiency for simulated events and background conditions of the experiment. The event detection efficiency was calculated with the simulation routine /16/. This routine takes into account the electromagnetic and nuclear interactions of the particles with the detector material as well as decays of unstable particles.

In order to reduce the number of e, μ, π the Cherenkov counters were used. When a particle traverses the counter, the total number of photoelectrons in the four photomultipliers of the counter equals

$$N_{pe} = N_0 d \left(1 - \frac{p_c^2}{p^2}\right) + D, \qquad (1)$$

where d is the particle pathlenth in the counter, N_0 is an average number of photoelectrons for a unit path and $\beta = 1$, p_c is a momentum threshold value for triggering of the counter, p is a particle momentum, D is an addition related to the light of the δ-electrons and reflecting cover of the counter. The trigger probability of one PM is equal to $\omega = 1 - \exp(-N_{pe}/4)$. Then the likelihood function looks like:

$$L = \sum_i -2\ln \frac{4!\,\omega_i^{k_i}(1-\omega_i)^{4-k_i}}{k_i!\,(4-k_i)!} \qquad (2)$$

where k is the number of triggered PM. The sum is calculated on the counters traversed by the charged particles.

a) $\Upsilon \to \gamma K^+K^-$

While considering the decay $\Upsilon \to \gamma K^+K^-$, for the momentum resolution improvement the maximum likelihood function method was used. This function is minimized over p_1 and p_2 and looks like:

$$S = \left(\frac{p_1 - p_{10}}{\sigma_p}\right)^2 + \left(\frac{p_2 - p_{20}}{\sigma_p}\right)^2 + \left(\frac{\pi - \theta}{\sigma_\theta}\right)^2, \qquad (3)$$

where p_1, p_2 are the optimum values of the momenta, θ is an angle between $\vec{p}_1 + \vec{p}_2$ and the photon outgoing direction, p_{10} and p_{20} are the measured values of the momenta. The masses of the charged particles were supposed to be equal to kaon mass and $E_1 + E_2 + P = 2E$. E_1 and E_2 are the energies of the charged particles, P is their total momentum, E is the beam energy. If only one momentum is measured, then the second term in (3) is omitted. K^+K^- invariant mass resolution in the vicinity of ξ (2.2) is ~ 200 MeV/c^2, the measured values p_{10} and p_{20} being used. Taking into account p_1 and p_2 essentially improves this resolution: 35 MeV/c^2 and 70 MeV/c^2, when both and only one momenta are measured, respectively.

An event was considered as a candidate for the decay $\Upsilon \to \gamma K^+K^-$, if the following conditions were satisfied:

1) only two charged particles were found in the coordinate chamber system;
2) the number of extra "sparks" outside the reconstructed particles tracks in coordinate chambers is not greater than 7;
3) at least one particle momentum is measured;
4) acollinearity angle of the charged particles is greater than 11.5°;
5) if a charged particles reaches a shower-range chamber, then the energy deposit in this chamber does not exceed 2 GeV electron being **supposed**;
6) $S < 9.$;
7) $L < 22.$;
8) at least one shower in the shower-range system is not a continuation of the track of charged particle;
9) if the photon traverses less than five coordinate chambers, then $\min(p_1, p_2) > 600$ MeV/c.

The distribution over the invariant mass of K^+K^- of the experimental events having passed these selection criteria in the interval from 1.5 GeV/c^2 to 4.0 GeV/c^2, is shown in fig.2. For the events $\Upsilon \to \gamma \xi$, $\xi \to K^+K^-$ the trigger efficiency was equal to 55.4% and 72.8% in different experimental cycles, the detection efficiency with the chosen selection criteria being equal to 9.6% and 14.2% respectively.

In the vicinity of ξ no events were found. The upper limit for the decay probability

$$B(\Upsilon \to \gamma \xi)\, B(\xi \to K^+K^-) < 2.\cdot 10^{-4} \quad (90\%\ \text{C.L.})$$

The result of CLEO for the upper limit for this decay equals $3.1 \cdot 10^{-5}$ /10/.

a) $\Upsilon \to \gamma \varphi\varphi \to \gamma K^+K^-K^+K^-$

In search for this decay the following selection criteria were chosen:

1) in the coordinate chamber system the four particles are reconstructed, all the momenta being measured;
2) the number of extra "sparks" aside from the charged particles tracks in coordinate chambers does not exceed eight;
3) the minimum momentum of the charged particles is greater than 550 MeV/c;
4) $L < 10.$;
5) at least one photon in the shower-range system is reconstructed;
6) the acollinearity angle between the photon outgoing direction and the total momentum of the charged particles is less than 8.1°.

No events pass these selection criteria. For the events of $\Upsilon \to \gamma \xi$, $\xi \to \varphi\varphi$, $\varphi \to K^+K^-$ the trigger efficiency was equal to 65.1% and 79.7% for different experimental cycles. The detection efficiency for the events equals 2.7% and 3.8% respectively. The invariant mass resolution of $K^+K^-K^+K^-$ is equal to ~ 100 MeV/c^2. The upper limit for the decay probability

$$B(\Upsilon \to \gamma \xi)\, B(\xi \to \varphi\varphi) < 3.\cdot 10^{-3} \quad (90\%\ \text{C.L.})$$

The before-mentioned detection efficiencies of the decays and upper limits for their probabilities are derived under the supposition that the spin of ξ equals zero. For the isotropic distribution in Υ and ξ decays the upper limits decrease by about 7%.

In conclusion the authors express their gratitude to the staff of the detector MD-1 and storage ring VEPP-4 for the help in work.

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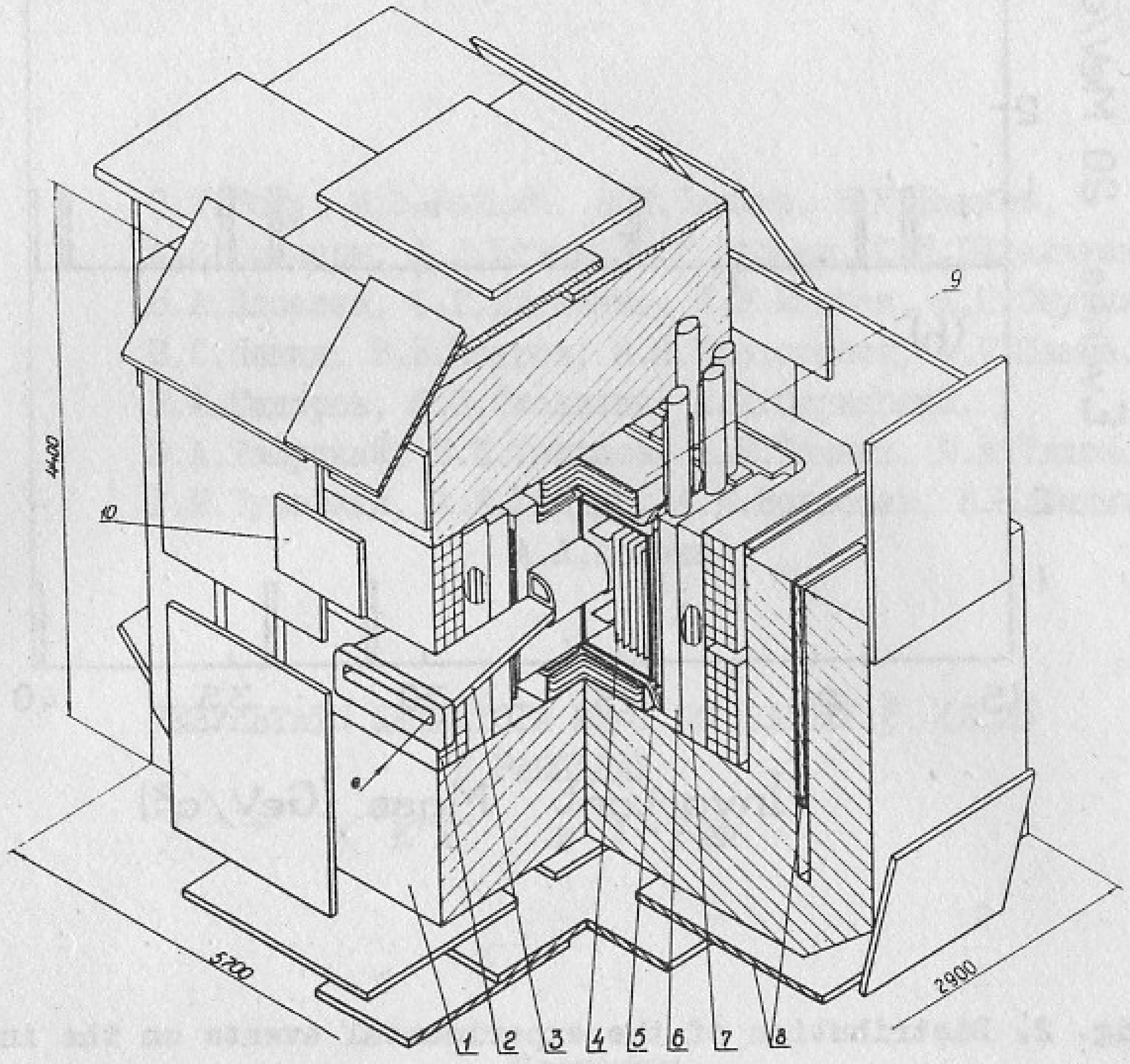

Fig. 1. Magnetic detector MD-1: 1 - yoke, 2 - copper winding, 3 - vacuum chamber, 4 - coordinate chambers, 5 - scintillation counters, 6 - gas Cherenkov counter, 7,9 - shower-range chambers, 8 - muon chambers,

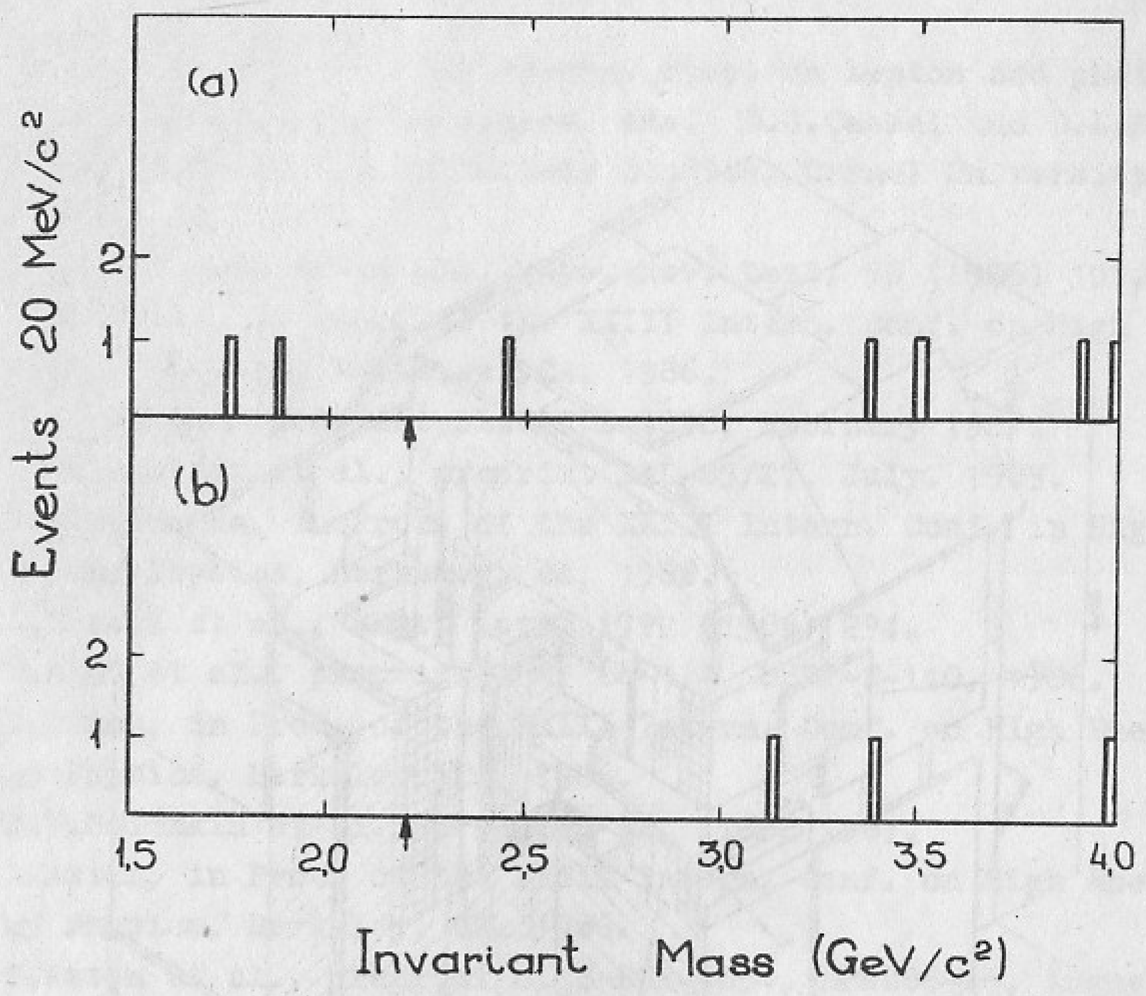

Fig. 2. Distribution of the experimental events on the invariant mass of K^+K^-, where both momenta (fig. 2a) and only one momentum (fig. 2b) are reconstructed. The arrow indicates the location of ξ (2.2).

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РЕЗУЛЬТАТЫ ДЕТЕКТОРА МД-1 ПО ПОИСКУ ξ (2.2)
В РАСПАДАХ
$\Upsilon \to \gamma K^+K^-$ и $\Upsilon \to \gamma \Phi\Phi$

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