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Search for exclusive radiative decays of $\Upsilon(1S)$ and $\Upsilon(2S)$ mesons

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Abstract. Using the ARGUS detector at the DORIS II storage ring we have searched for radiative decays $\Upsilon(1S) \rightarrow \gamma X$, where X decays into two oppositely charged pions, kaons, or protons. Upper limits on branching fractions are presented. In the $\pi^+\pi^-$ invariant mass region 290–570 MeV/c^2 the upper limit obtained varies from 3 to 4.5×10^{-5}. These values are lower than the theoretical prediction of about 5×10^{-5} for Higgs production, which includes perturbative QCD radiative corrections to the Wilczek formula and the estimate $\mathrm{Br}(H^0 \rightarrow \pi^+\pi^-) \approx 45\%$, accounting for Higgs coupling to gluons via heavy quark loops. Previous experimental results do not exclude the existence of a standard minimal Higgs in this mass region.

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One of the reasons for the interest in radiative Υ decays is the possibility of searching for the Higgs particle. In the simplest version of the standard model there is only one neutral Higgs with well defined coupling to quarks, leptons and intermediate bosons. Unfortunately its mass is not fixed by the theory. The often quoted lower limit of about 7 GeV [1] is based on the assumption that the mass of the t-quark is not too large and that there is no other heavy fermion (no fourth generation). However the recent observation of large $B^0 \bar{B}^0$ mixing [2] indicates that the mass of the t-quark may be substantially larger than expected, and therefore the limit on the Higgs mass could be lower. For the minimal Higgs sector, Wilczek calculated the branching ratio for $V \to \gamma H^0$ [3]:

$$\mathrm{Br}(V \to \gamma H^0) = \frac{G_F M_V^2}{4\sqrt{2}\pi\alpha}\left(1 - \frac{M_{H^0}^2}{M_V^2}\right) \mathrm{Br}(V \to \mu^+\mu^-),$$

where M_V is the mass of the vector meson V, M_{H^0} is the mass of the Higgs, G_F is the Fermi constant and α is the fine structure constant. For the $\Upsilon(1S)$, $\mathrm{Br}(V \to \gamma H^0)$ is 10 times that for J/ψ. The prediction of the Wilczek formula ($\sim 2.2 \times 10^{-4}$) is decreased by a factor of two because of the perturbative QCD radiative corrections [4]. In more complicated models with several Higgs doublets, Higgs couplings to quarks and leptons can be either enhanced or suppressed in comparison with the prediction of the minimal model.

Experiments do not provide much information about the Higgs (for a recent discussion see for example [5]). Studies of nuclear reactions exclude the standard Higgs boson with $M_H \leqq 13$ MeV/c^2. The limits for higher masses come from searches for $K^+ \to \pi^+ H \to \pi^+ e^+ e^-$ and $\eta' \to \eta H \to \eta \mu^+ \mu^-$. These firmly exclude the mass interval from 50 MeV/c^2 to $2\,m_\pi$. There also exists a preliminary result of the CUSB group [6]. They obtained an upper limit for $\mathrm{Br}(\Upsilon \to \gamma H^0)$ which is lower than theoretical predictions for a standard minimal Higgs boson with masses 0.6 GeV/c$^2 < M_H <$ 3.9 GeV/c^2. The mass interval 0.28 GeV/c$^2 < M_H <$ 0.6 GeV/c^2 has not yet been excluded. Light Higgs bosons can also be copiously produced in B-meson decays. However theoretical predictions for exclusive B-meson decays into Higgs are very uncertain and even the inclusive yield depends drastically on the unknown mass of the t-quark (for a discussion see for example [7]). For models with more than one Higgs doublet searches for Higgs bosons in Υ and B-decays are complementary.

Another interesting question relates to two-body radiative decays of the Υ meson. For these decays one can expect at least a factor $\left(\frac{e_b^2}{e_c^2}\right) \times \left(\frac{m_c^2}{m_b^2}\right) \sim 1/40$ suppression in comparison with J/ψ decay [8] and correspondingly $\mathrm{Br}(\Upsilon \to \gamma(\eta, \eta', \xi, f_2(1720))$ at the level of 10^{-4} to a few times 10^{-5}. There also exist more elaborate theoretical predictions for $\Upsilon(1S) \to \gamma f_2(1270)$ and $\Upsilon(1S) \to \gamma f_2'(1525)$ [9] at the same level, which is close to our experimental sensitivity.

The data used for this analysis were collected with the ARGUS detector [10] at the DORIS storage ring and correspond to an integrated luminosity of 39.5 pb^{-1} at the $\Upsilon(1S)$ energy and 27.7 pb^{-1} at the $\Upsilon(2S)$ energy. These two data samples contain 400000 ± 19000 $\Upsilon(1S)$ decays and 98000 ± 7000 $\Upsilon(2S)$ decays respectively. The following decay modes with two charged particles were considered:

1) $\Upsilon \to \gamma \pi^+ \pi^-$;
2) $\Upsilon \to \gamma K^+ K^-$;
3) $\Upsilon \to \gamma p \bar{p}$.

Events were accepted as candidates for these reactions if the following criteria were satisfied:

- two oppositely charged tracks were found in the drift chamber that point to the main vertex;
- $\cos\alpha > -0.5$, where α is the angle between the two charged particles;
- there was at least one shower in the electromagnetic calorimeter with an energy greater than 2.5 GeV, which was not matched with a track found in the drift chamber;
- difference between the total measured energy and the known center of mass energy was less than 3σ, where σ is the estimated experimental resolution.

9831 events taken at the $\Upsilon(1S)$ energy passed these criteria. The main sources of background for the discussed reactions were QED events (radiative Bhabha events, radiative muon pairs, and $e^+e^- \to \gamma\gamma$ events where one of the photons converts into an electron-positron pair).

The identification of electrons and muons is performed in the ARGUS detector with high efficiency and low misidentification probability. For electron identification, information from all detector components is used coherently by combining the measurements into an overall likelihood probability L. The available information consists of dE/dx and TOF measurements, and the magnitude and topology of energy deposition in the shower counters. To reject electrons we demanded that each charged track has $L < 50\%$ for the electron hypothesis. In order to suppress $\mu\mu\gamma$ events, we rejected tracks with hits in the outer layers of the muon chambers; 492 $\mu^+\mu^-\gamma$ events were rejected using this cut. The invariant mass distribution for $\mu^+\mu^-$ pairs was in a good agreement in shape and absolute value with that obtained by Monte Carlo studies with with the same luminosity as collected in the experiment. About 7% of the hadronic events were rejected due to these cuts, designed to suppress QED events.

In order to further suppress QED events and to ensure good trigger conditions, $|\cos\theta|<0.7$ was required for polar angle of energetic photon. To reject background from multihadron events we allowed only one additional photon with $E_\gamma>120$ MeV. The efficiency of this cut (>0.97) was obtained from cosmic ray data taken simultaneously with the experimental data.

The 454 events which satisfied all the criteria mentioned above were subjected to a four constraint kinematical fit to each of the reactions discussed. Events with $\chi^2<16$ were accepted. The efficiency of the χ^2 cut was determined by Monte Carlo studies to be 0.95. After applying the four constraint fit the mass resolution (σ) for the invariant mass of the two charged particles varied from 4 MeV/c^2 for $M=0.4$ GeV/c^2 to about 15 MeV/c^2 for $M=3$ GeV/c^2. The resolution obtained in the low mass region is two orders of magnitude better than that obtained from studies of the inclusive photon spectrum alone. Even for the best photon spectrometers, such as CUSB [11], the entire recoil mass region below 1 GeV/c^2 corresponds to an interval of photon energies smaller than the photon energy resolution.

Figure 1a shows the $\pi^+\pi^-$ invariant mass for candidate events with $M_{\pi\pi}<3.5$ GeV/c^2. One can see a prominent peak in the ρ mass region. This peak is well described by a relativistic p-wave Breit-Wigner, using the current average values for the mass and width of the ρ meson [12]. The decay $\Upsilon(1S)\to\gamma\rho^0$ is forbidden by conservation of charge parity, but the radiative process $e^+e^-\to\gamma\rho^0$ may arise from continuum production. To study the nature of this peak we repeated the analysis for the data (80 pb^{-1}) collected at the $\Upsilon(4S)$ resonance, which for these reactions can be considered as a pure continuum sample. The $\pi^+\pi^-$-invariant mass distribution for these events is shown in Fig. 1b. The number of events in the ρ signals of Fig. 1a and b are in good agreement, if one takes into account the difference in luminosity and the energy dependence of the cross section. This is further evident in Fig. 1c which shows the result of the continuum subtraction; one can also see that there is no significant excess of events due to the reaction $\Upsilon(1S)\to\gamma\pi^+\pi^-$. We also generated an equal sample of continuum Monte Carlo events representing the process $e^+e^-\to\gamma\pi^+\pi^-$. The result is shown as a histogram in Fig. 1a and agrees well with the data, both in shape and in absolute value. We therefore conclude that the ρ peak observed is well explained as arising from continuum production both on the basis of the experimental distribution of continuum events and from the Monte Carlo simulation of continuum production.

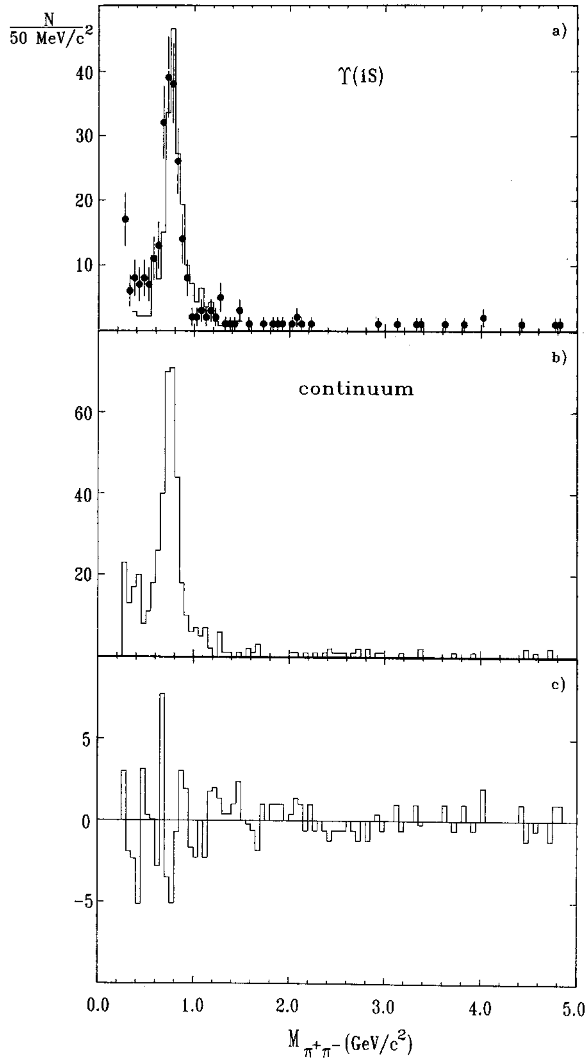


Fig. 1a–c. $\pi^+\pi^-$ invariant mass distribution for **a** $\Upsilon(1S)$ without continuum subtraction (the histogram represents a Monte Carlo calculation of the process $e^+e^-\to\gamma\pi^+\pi^-$, absolutely normalized); **b** continuum (data at $\Upsilon(4S)$ energy are used); **c** $\Upsilon(1S)$ after continuum subtraction

On the low mass side of the ρ peak there exists some enhancement, which is a residue of QED background and a reflection from the reaction $e^+e^-\to\gamma\phi\to\gamma K^+K^-$. In order to suppress such events a few additional cuts were applied for $\pi^+\pi^-$ invariant masses in the region 0.28–0.7 GeV/c^2:

- total shower energy deposited by two charged particles should be less than 1.7 GeV (to suppress radiative Bhabha events and $e^+e^-\to\gamma\gamma$ events where one photon converted);
- $|\cos\theta|<0.5$ for energetic photon (for further suppression of continuum events which peak at large $|\cos\theta|$);

• $(L\hat{K}-L_\pi)<0.2$ where L_K and L_π are likelihood probabilities for the kaon and pion hypotheses respectively (to minimize the contribution from misidentified kaons from the continuum reaction $e^+e^- \rightarrow \gamma\phi \rightarrow \gamma K^+K^-$, which populates the region of small $\pi^+\pi^-$ invariant mass).

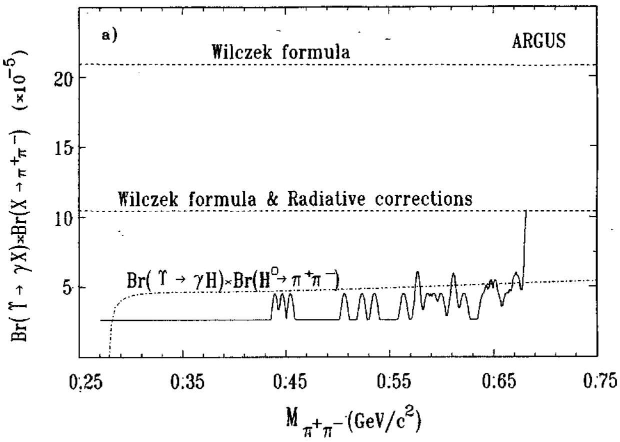
Only a few events satisfied these additional criteria. The reconstruction efficiencies for the investigated decays were determined from Monte Carlo studies and also checked using experimental data. The trigger efficiency was checked using radiative Bhabha events. This efficiency was larger than 96% during the entire period of data taking and over the full energy range considered. Final efficiencies were 0.22 for $0.28\ \mathrm{GeV/c^2} < M_{\pi^+\pi^-} < 0.7\ \mathrm{GeV/c^2}$ and varied smoothly from 0.45 for $M_{\pi^+\pi^-} = 1\ \mathrm{GeV/c^2}$ to 0.35 for $M_{\pi^+\pi^-} = 3.5\ \mathrm{GeV/c^2}$. For K^+K^- and $p\bar{p}$ final states the efficiencies were 0.40 and 0.45 respectively, for $M_{K^+K^-}$ or $M_{p\bar{p}} < 2.5\ \mathrm{GeV/c^2}$, and decreased by 15% at invariant masses of $3.5\ \mathrm{GeV/c^2}$. These values included corrections for the angular anisotropy of the decay $\Upsilon \rightarrow \gamma H^0$ [9].

Figure 2a shows the 90% confidence level upper limit on the branching ratio for the reaction $\Upsilon(1S) \rightarrow \gamma\pi^+\pi^-$ in the $\pi^+\pi^-$ invariant mass region 0.28–0.7 GeV/c^2. To be conservative in calculating upper limits on branching ratios, no continuum subtraction was done. This is the most interesting region because of the expected large $\mathrm{Br}(H^0 \rightarrow \pi^+\pi^-)$. There are only two sizable decay modes for Higgs masses between 0.3 GeV/c^2 and $2m_K$, namely $H \rightarrow \mu^+\mu^-$ and $H \rightarrow \pi\pi$. Moreover, in this region their relative branching ratios can be calculated using the relationship due to Voloshin [13]:

$$\frac{\Gamma(H \rightarrow \pi\pi)}{\Gamma(H \rightarrow \mu\mu)} = \frac{1}{27}\frac{M_H^2}{m_\mu^2}\frac{\left(1+\frac{11}{2}\frac{m_\pi^2}{M_H^2}\right)^2}{\left(1-\frac{4m_\mu^2}{M_H^2}\right)} \cdot \frac{|p_\pi|}{|p_\mu|}$$

which yields a value of about two. From Fig. 2a it is evident that for $290\ \mathrm{MeV/c^2} < M_{\pi^+\pi^-} < 570\ \mathrm{MeV/c^2}$ our upper limit is lower than the theoretical prediction for minimal standard Higgs, taking into account perturbative QCD corrections [4] and using the expected value for $\mathrm{Br}(H \rightarrow \pi^+\pi^-)$ [13]. Over most of this region our upper limit is lower than theoretical predictions by a factor of 1.7, providing some room for uncertainties in the predictions.

Figure 2b shows the 90% confidence level upper limit on the branching ratio for the reaction $\Upsilon(1S) \rightarrow \gamma\pi^+\pi^-$ for the $\pi^+\pi^-$ invariant mass region 1–3.5 GeV/c^2. In this region the upper limit obtained is at the level of the theoretical predictions for the



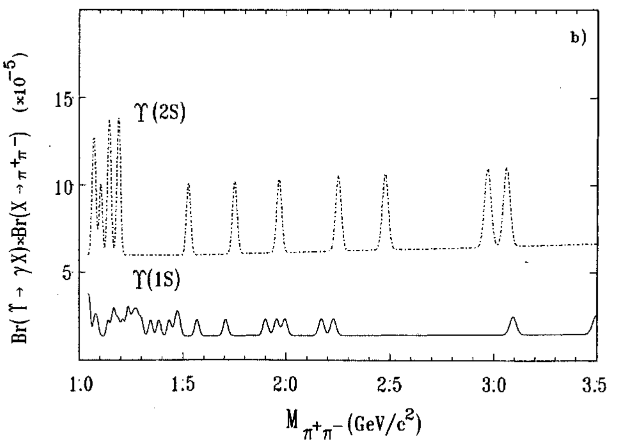


Fig. 2. a 90% confidence level upper limit on branching fraction as a function of the invariant mass for $\Upsilon(1S) \rightarrow \gamma\pi + \pi -$ (solid line). The dashed line corresponds to the uncorrected and corrected Wilczek formulae. The dotted-dashed line corresponds to the theoretical upper limit for the $\mathrm{Br}(\Upsilon \rightarrow \gamma H^0)\,\mathrm{Br}(H^0 \rightarrow \pi^+\pi^-)$. **b** 90% confidence level upper limit as a function of the invariant mass for $\Upsilon(1S) \rightarrow \gamma\pi + \pi -$ (solid line), $\Upsilon(2S) \rightarrow \gamma\pi + \pi -$ (dashed line)

minimal standard Higgs, namely $\sim(1\text{–}1.5) \times 10^{-5}$. However it is difficult to make definite conclusions in this mass region because of large theoretical uncertainties for $\mathrm{Br}(H \rightarrow \pi^+\pi^-)$. In the same figure the 90% confidence level upper limit for the branching ratio of the reaction $\Upsilon(2S) \rightarrow \gamma\pi^+\pi^-$ is also shown.

Figure 3a shows 90% confidence level upper limits on the branching ratios for reactions $\Upsilon(1S) \rightarrow \gamma K^+K^-$, $\Upsilon(1S) \rightarrow \gamma p\bar{p}$ and $\Upsilon(2S) \rightarrow \gamma K^+K^-$, $\Upsilon(2S) \rightarrow \gamma p\bar{p}$. To suppress a strong reflection from the reaction $e^+e^- \rightarrow \gamma\rho^0 \rightarrow \gamma\pi^+\pi^-$ due to $\pi-K$ or $\pi-p$ misidentification, we demanded for each charged particle that $(L_K-L_\pi)>0.2$ for the $\Upsilon \rightarrow \gamma K^+K^-$ reaction and that $(L_p-L_\pi)>0.2$ for the $\Upsilon \rightarrow \gamma p\bar{p}$ reaction. The cut was applied only in the region of invariant masses where reflection was sizable, namely $1\ \mathrm{GeV/c^2} < M_{K^+K^-} < 1.6\ \mathrm{GeV/c^2}$ and $2.0\ \mathrm{GeV/c^2} < M_{p\bar{p}}$

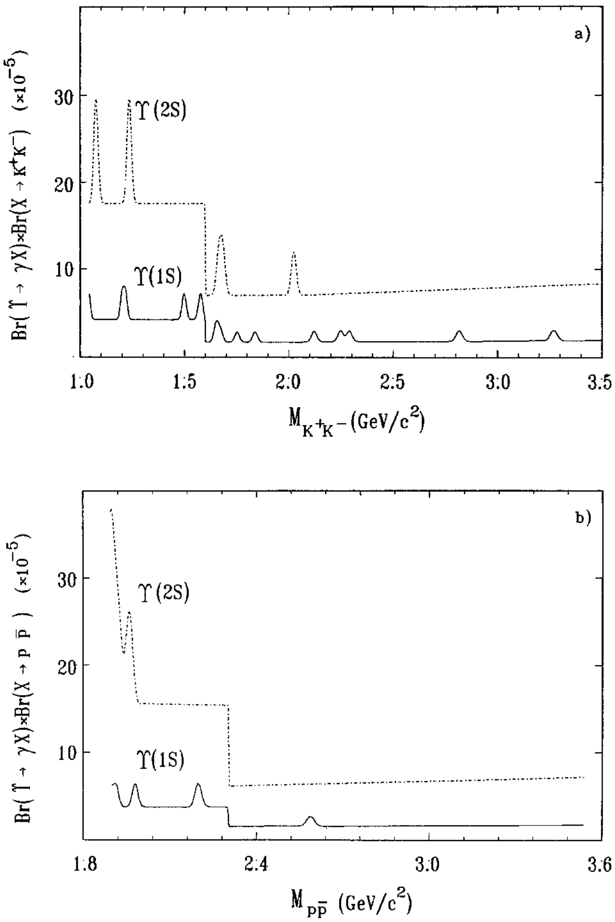


Fig. 3a and b. 90% confidence level upper limits on branching fractions as a function of the invariant mass for **a** $\Upsilon \to \gamma K^+ K^-$; **b** $\Upsilon \to \gamma p \bar{p}$

Table 1. Upper limits at 90% confidence level on branching ratios for exclusive radiative Υ-decays

Reaction	ARGUS	Theory [9]
$Br(\Upsilon(1S) \to \gamma f_2(1270)) \times Br(f_2 \to \pi^+\pi^-)$	$< 7.3 \times 10^{-5}$	$\sim 7 \times 10^{-5}$
$Br(\Upsilon(1S) \to \gamma f_2'(1525)) \times Br(f_2' \to K^+K^-)$	$< 6.9 \times 10^{-5}$	$\sim 2 \times 10^{-5}$
$Br(\Upsilon(1S) \to \gamma f_2(1720)) \times Br(f_2 \to K^+K^-)$	$< 5.0 \times 10^{-5}$	
$Br(\Upsilon(1S) \to \gamma f_2(1720)) \times Br(f_2 \to \pi^+\pi^-)$	$< 2.1 \times 10^{-5}$	
$Br(\Upsilon(1S) \to \gamma \xi_2(2230)) \times Br(\xi \to K^+K^-)$	$< 2.9 \times 10^{-5}$	
$Br(\Upsilon(2S) \to \gamma f_2(1270)) \times Br(f_2 \to \pi^+\pi^-)$	$< 13.5 \times 10^{-5}$	
$Br(\Upsilon(2S) \to \gamma f_2'(1525)) \times Br(f_2' \to K^+K^-)$	$< 19.0 \times 10^{-5}$	
$Br(\Upsilon(2S) \to \gamma f_2(1720)) \times Br(f_2 \to K^+K^-)$	$< 11.3 \times 10^{-5}$	
$Br(\Upsilon(2S) \swarrow \gamma f_2(1720)) \times Br(f_2 \to \pi^+\pi^-)$	$< 5.9 \times 10^{-5}$	
$Br(\Upsilon(2S) \swarrow \gamma \xi(2230)) \times Br(\xi \to K^+K^-)$	$< 6.8 \times 10^{-5}$	

< 2.3 GeV/c². The efficiency of this cut (about 40%) was obtained from Monte Carlo studies and was checked using well identified kaons from the decay $D^{*+} \to \pi^- D^0 \to \pi^+ K^- \pi^+$.

Table 1 summarizes the upper limits for several exclusive Υ decays, after continuum subtraction. Theoretical predictions presented in the table are calculated using experimental values of $Br(J/\psi \to \gamma f_2(1270) \to \gamma \pi^+\pi^-) = (7.5 \pm 0.3 \pm 1.12) \times 10^{-4}$ and $Br(J/\psi \to \gamma f_2'(1525) \to \gamma K^+K^-) = (2.5 \pm 0.6 \pm 0.4) \times 10^{-4}$ [14]. Our upper limit on $Br(\Upsilon(1S) \to \gamma f_2(1270))$ is more stringent than the limit of 8.1×10^{-4} recently obtained by the Crystal Ball group [15] and already close to the theoretical prediction. According to [16] radiative decays are about 3% of three-gluon decays for the $\Upsilon(1S)$. However, we do not observe radiative decays of $\Upsilon(1S)$ with a hadron pair h^+h^- (where h^+h^- represents $\pi^+\pi^-$, K^+K^-, $p\bar{p}$) in the final state, yielding $Br(\Upsilon(1S) \to \gamma h^+ h^-) < 3 \times 10^{-4}$ at 90% confidence level for $M_{h^+h^-} < 3.5$ GeV/c².

The CLEO group has claimed smaller upper limits than ARGUS for most of these decays [17], although they has a factor of 1.5 times fewer $\Upsilon(1S)$ decays and a factor of 2 times smaller efficiency. The reason for the better limits is a complete absence of background. However, they only reported three events $e^+e^- \to \gamma \rho^0 \to \gamma \pi^+\pi^-$ for which we observe 170 in the ρ mass region 0.6–0.95 GeV/c². Taking into account a factor of 3.2 smaller luminosity and a factor of 2 smaller efficiency in the CLEO experiment, one could expect more than 20 ($e^+e^- \to \gamma \rho^0$) event's.

In conclusion, no structures are seen in decays of the $\Upsilon(1S)$ into a photon and two charged hadrons at a branching ratio level of 2×10^{-5} for $\pi^+\pi^-$ and at a level of 4×10^{-5} for K^+K^- and $p\bar{p}$ in the invariant mass region 1–3.5 GeV/c².

For $\pi^+\pi^-$ invariant masses between 290 and 570 MeV/c² our upper limit is lower than the theoretical prediction for minimal standard Higgs production, including perturbative radiative corrections to the Wilczek formula and using an estimate for $Br(H^0 \to \pi^+\pi^-)$, which accounts for Higgs coupling to gluons via heavy quark loops.

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References

1. A. Linde: JETP Lett. 23 (1976) 64; S. Weinberg: Phys. Rev. Lett. 36 (1976) 294
2. H. Albrecht et al. ARGUS Coll.: Phys. Lett. B192 (1987) 245
3. F. Wilczek: Phys. Rev. Lett. 39 (1977) 1304
4. M.I. Vysotsky: Phys. Lett. B97 (1980) 159; J. Ellis et al.: Phys. Lett. B158 (1985) 417; P. Nason: Phys. Lett. B175 (1986) 223
5. A.A. Ansel'm et al.: Sov. Phys. Usp. 28 (1985) 113; M.V. Danilov: Proceedings of Int. Symp. on Decays of Heavy Flavours,

Heidelberg, (1986) p. 49; R.S. Willey: Phys. Lett. B173 (1986) 480
6. J. Lee-Franzini: Proceedings of Int. Symp. on Lepton and Photon Interactions at High Energies, Hamburg, (1987) p. 166; M. Narain et al. CUSB Coll. Cornell preprint (1987)
7. P. Avery et al. CLEO Coll.: Contributed paper 258 to the Int. Symp. on Lepton and Photon Interactions at High Energies, Hamburg, (1987); B. Grinstein et al.: LBL preprint LBL-25095 (1988)
8. S.-H.H. Tye: Proceeding of the 1982 DPF Summer Study on Elementary Particle Physics and Future Facilities, Snowmass, Colorado
9. J.G. Körner et al.: Nucl. Phys. B229 (1983) 115
10. H. Albrecht et al. ARGUS Coll.: DESY preprint DESY 88-080 (1988)
11. P. Franzini et al. CUSB Coll.: Phys. Rev. D35 (1987) 2883
12. Particle Data Group M. Aguilar-Benitez et al.: Review of particle properties. Phys. Lett. B170 (1986) 1
13. M.B. Voloshin: Preprint ITEP-153 (1985); Yad. Fiz. 44 (1986) 738
14. J. Augustin et al.: Z. Phys. C – Particles and Fields 36 (1987) 369; Phys. Rev. Lett. 60 (1988) 2238
15. P. Schmitt et al. Crystal Ball Coll.: DESY preprint DESY 88-031 (1988); SLAC-PUB-4568 (1988)
16. R.D. Schamberger et al. CUSB Coll.: Phys. Lett. B138 (1984) 225; S.E. Csorna et al. CLEO Coll.: Phys. Rev. Lett. 56 (1986) 1222; H. Albrecht et al. ARGUS Coll.: Phys. Lett. B199 (1987) 291
17. A. Bean et al.: Phys. Rev. D34 (1986) 905