ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ СО АН СССР

**A.E. Blinov, V.E. Blinov, A.E. Bondar, A.D. Bukin,
V.R. Groshev, S.G. Klimenko, A.P. Onuchin,
V.S. Panin, A.G. Shamov, V.A. Sidorov,
Yu.I. Skovpen, V.A. Tayursky, V.I. Telnov,
Yu.A. Tikhonov, A.E. Undrus,
A.I. Vorobiov, V.N. Zhilich**

SEARCH FOR DECAY $\Upsilon \to \rho^0\pi^0$

PREPRINT 90-44

НОВОСИБИРСК

Search for Decay $\Upsilon \to \rho^0\pi^0$

A.E. Blinov, V.E. Blinov, A.E. Bondar, A.D. Bukin,
V.R. Groshev, S.G. Klimenko, A.P. Onuchin,
V.S. Panin, A.G. Shamov, V.A. Sidorov,
Yu.I. Skovpen, V.A. Tayursky, V.I. Telnov,
Yu.A. Tikhonov, A.E. Undrus,
A.I. Vorobiov, V.N. Zhilich

Institute of Nuclear Physics
630090, Novosibirsk, USSR

ABSTRACT

Experiment was carried out with MD-1 detector at the electron-positron collider VEPP-4. The upper limit of $B(\Upsilon \to \rho^0\pi^0) < 3.3 \cdot 10^{-4}$ with 90% C.L. was obtained.

1. INTRODUCTION

One of the interesting questions of Υ-physics is a search for Υ-meson decays with low multiplicity. In the present paper the results of the experiment on the search for the decay $\Upsilon \to \rho^0\pi^0$ are presented. The theoretical estimation of the value $B(\Upsilon \to \rho\pi)/B(J/\psi \to \rho\pi)$ gives $(M_{J/\psi}/M_\Upsilon)^6 \sim 10^{-3}$ [1]. Using the known experimental value of $B(J/\psi \to \rho\pi) = 1.28 \cdot 10^{-2}$ [2] one can obtain $B(\Upsilon \to \rho\pi) \sim 10^{-5}$. At present the only experimental limit for $B(\Upsilon \to \rho^0\pi^0) < 6.9 \cdot 10^{-4}$ (90% C.L.) exists obtained with LENA detector [3].

The energy of π^0 in the decay $\Upsilon \to \rho^0\pi^0$ is equal to 4.5 GeV. The resolution of our detector does not allow to reconstruct both photons of the decay of such π^0, so the events are detected as two charged particles and one γ-quantum.

The same final state can be produced in the following processes: $e^+e^- \to \rho^0\gamma$, $e^+e^- \to \mu^+\mu^-\gamma$, $e^+e^- \to e^+e^-\gamma$ and $e^+e^- \to \gamma\gamma$ (with conversion of one γ-quantum to e^+e^--pair at the beam-pipe). These processes are the main background processes for the decay under investigation.

2. EXPERIMENT

Experiment was carried out with the detector MD-1 at the storage ring VEPP-4. The description of the detector can be found in

[4]. The integrated luminosity, equal to 6.5 pb^{-1} at the Υ-resonance and 2.7 pb^{-1} around it, was collected from October 1983 to July 1984. This run consisted of two cycles with the different trigger conditions the integrated luminosity in which was 4.5 and 4.7 pb^{-1}. Besides integrated luminosity of 15.6 pb^{-1} was collected from October 1984 to July 1985 in the center of mass energy range from 7.2 to 10.4 GeV.

The number of events recorded on the tapes equals $\sim 4 \cdot 10^7$. The number of detected Υ-mesons is equal to 10^5.

3. SIMULATION

The selection efficiency of the events was determined by Monte Carlo simulation. The simulation can be divided into two parts.

The first one is the production of particles in e^+e^--annihilation. For simulation of the decay $\Upsilon \to \rho^0\pi^0$ we used the following dependence of the decay probability on the final particles momenta:

$$\frac{dw}{dR} \sim |F_\pi(m^2_{\pi^+\pi^-})|^2 [\vec{q}_+(\vec{n}\,\vec{q}_-) - \vec{q}_-(\vec{n}\,\vec{q}_+)]^2, \quad (1)$$

where R is the phase space of three particles (π^+, π^-, π^0); $\vec{q}_+$, $\vec{q}_-$ are π^+- and π^--momenta, respectively; $\vec{n}$ is the direction along the beam line; $m_{\pi^+\pi^-}$ is the invariant mass of $\pi^+\pi^-$-system. F_π is the π-meson form factor, the expression for which could be found in [5].

The cross section of the process $e^+e^- \to \rho^0\gamma$ ($\rho^0 \to \pi^+\pi^-$) was derived, using the formulas for the photon emission from the initial state obtained in [6]. For simulation of the process $e^+e^- \to \mu^+\mu^-\gamma$ the computer code [7] was used, for $e^+e^- \to e^+e^-\gamma$ the computer code [8]. The process $e^+e^- \to \gamma\gamma$ was simulated according to the known cross section [9].

For all these processes we took into account the radiative corrections, formulas for which were taken from [10]. The value of these corrections depends on the invariant mass of charged particles and the outgoing angle of the photon with respect to the beam line. For our experimental conditions the decrease of electrodynamical cross sections, listed above, is about 20%.

The second part of event simulation is tracking of particle through the detector. This computer code takes into account the

electromagnetic and nuclear interactions of particles with the matter of detector and decays of unstable particles [11].

4. EXPERIMENTAL DATA PROCESSING

Earlier the radiative decays of Υ-meson into K^+K^- were investigated with the detector MD-1. In our paper [12] the detailed description of the experiment on a search for the decay $\Upsilon \to \gamma\xi(2.2) \to \gamma K^+K^-$ has been presented. For the search of decay $\Upsilon \to \rho^0\pi^0$ we used the same selection criteria. The only difference is the assumption about the charged particles mass. In present paper the charged particles were supposed to be pions. Below these selection criteria are briefly presented, the detailed description of which can be found in [12]:

1. Two charged particles and at least one photon are reconstructed.
2. Acollinearity angle of the charged particles is greater than 11.5°.
3. Number of hits outside the charged particles tracks in coordinate chambers is not more than seven.
4. If a charged particle reaches the shower-range chamber, the detected energy losses in this chamber do not exceed those of a 2 GeV electron.
5. The log-likelihood function S, which is the kinematic characteristics of three particle decay, is greater than -4.5 (see definition of S in [12]).
6. The log-likelihood function L, which analyzes the information of Cherenkov counters, is greater than -3.5 (see definition of L in [12]).
7. If a photon crosses less than five coordinate chambers, a minimum momentum of charged particles is greater than 600 MeV/c.

The number of events, having passed these selection criteria and having $m_{\pi^+\pi^-} < 4$ GeV/c^2, is shown in the Table. The resolution on invariant mass of charged particles in this region of $m_{\pi^+\pi^-}$ is equal to 35 MeV/c^2.

In this Table the number of events obtained by simulation of background processes $e^+e^- \to \rho^0\gamma$ and $e^+e^- \to \mu^+\mu^-\gamma$ is presented. In Fig. 1,*a*,*b* their distributions over $m_{\pi^+\pi^-}$ is shown, where the

Table

The Numbers of Experimental Events and Events of Simulated Processes $e^+e^-\to\rho^0\gamma$ and $e^+e^-\to\mu^+\mu^-\gamma$

	Resonance	Continuum
Experiment	19 ± 4.4	71 ± 8.4
$e^+e^-\to\rho^0\gamma$	5.2 ± 0.7	18.6 ± 2.1
$e^+e^-\to\mu^+\mu^-\gamma$	11.3 ± 1.2	37.2 ± 2.2

number of simulated events corresponds to the integrated luminosity of 61.4 and 55.2 pb^{-1} for the processes $e^+e^-\to\rho^0\gamma$ and $e^+e^-\to\mu^+\mu^-\gamma$, respectively. Here the fitting curves are also shown, $P(\chi^2)$ is equal to 70 and 50% for the processes $e^+e^-\to\rho^0\gamma$ and $e^+e^-\to\mu^+\mu^-\gamma$, respectively.

The number of events of other background processes is less then the number of events mentioned above. We estimated the number of background events of the process $e^+e^-\to e^+e^-\gamma$ to be about 30% of that due to the process $e^+e^-\to\mu^+\mu^-\gamma$. The process $e^+e^-\to\gamma\gamma$ with the conversion of one photon at the beam pipe of the detector into e^+e^--pair is also one of the possible background sources. The number of events of this process is about 20% of that due to the process $e^+e^-\to\rho^0\gamma$.

As one can see in the Table, the background processes $e^+e^-\to\rho^0\gamma$, $e^+e^-\to\mu^+\mu^-\gamma$ do not describe entirely the experiment. Therefore we tried to fit the experimental events with the sum of contributions from the decay $\Upsilon\to\rho^0\pi^0$, two background processes $e^+e^-\to\rho^0\gamma$, $e^+e^-\to\mu^+\mu^-\gamma$ and unknown background.

In Fig. 1,*c* the distribution of the simulated events of the decay $\Upsilon\to\rho^0\pi^0$ over $m_{\pi^+\pi^-}$ is shown (all selection criteria are applied). $P(\chi^2)$ is equal to 35% for fitting curve. The number of $2.2\cdot10^3$ events of the decay was used. The selection efficiency is 7.3%.

In Fig. 2 the distributions of experimental events and the sum of contributions of simulated processes $e^+e^-\to\rho^0\gamma$ and $e^+e^-\to\mu^+\mu^-\gamma$ over $m_{\pi^+\pi^-}$ are shown. We assumed that the cross section of unknown background $\sigma_B\sim s^{-1}$. The validity of this assumption was checked on the statistics collected outside the resonance region. Dependence σ_B of $m_{\pi^+\pi^-}$ was approximated in two ways: uniform on $m_{\pi^+\pi^-}-\sigma_{B1}=a/s$ or quadratic on $m_{\pi^+\pi^-}-\sigma_{B2}=b(m_{\pi^+\pi^-}-c)^2/s$, where a, b, c are free parameters fitted to experiment. Using this

parametrization we obtained for the fitted events of continuum the value of $P(\chi^2)$ equal to 2.5 and 30% for uniform and quadratic over $m_{\pi^+\pi^-}$ background, respectively. In Fig. 3 events of continuum and resonance are shown with quadratic parametrization σ_B of $m_{\pi^+\pi^-}$.

We obtained the upper limit for the decay probability $\Upsilon\to\rho^0\pi^0$:

$$B(\Upsilon\to\rho^0\pi^0)<3.3\cdot10^{-4} \quad (90\%\ \text{C.L.}).$$

We checked the dependence of this result on the type of approximation of unknown background and on the region of beam energy used in the experiment. The difference from the cited result does not exceed 20%.

When our paper was ready for publication, we have received a preprint [13], in which the CLEO detector placed the upper limit for $B(\Upsilon\to\rho^0\pi^0)$ lower than our limit given above.

The authors express their gratitude to the staff of VEPP-4 collider and MD-1 detector for carrying out the experiment.

REFERENCES

1. *S.J. Brodsky, G.P. Lepage.* In: Proc. of the Conf. on High Energy Physics with Polarized Beam and Polarized Tagets, eds. C. Joseph, J. Soffer (Lausanne, 1980) p.169;
   V.L. Chernyak, A.R. Zhitnitsky. Phys. Rep. 112 (1984) 173.
2. Word average value from Particle Data Table: Phys. Lett. 204 (1988) 1.
3. *B. Niczyporuk et al.* Z. Phys. C17 (1983) 197.
4. *S.E. Baru et al.* In: Proc. of the Int. Conf. on Instr. for Colliding Beam Physics (SLAC, Stanford, 1982) p.241;
   S.E. Baru et al. Preprint INP 83-39, Novosibirsk, 1983.
5. *G.J. Gounaris, J.J. Sakurai.* Phys. Rev. Lett. 21 (1968) 244.
6. *F.A. Berends, R. Kleiss.* Nucl. Phys. B178 (1981) 141.
7. *F.A. Berends, R. Kleiss.* Comp. Phys. Comm. 29 (1983) 185.
8. *A.D. Bukin.* Preprint INP 85-124, Novosibirsk, 1985.
9. *P.A.M. Dirac.* Proc. Cambr. Phil. Soc. 26 (1930) 361.
10. *F.A. Berends, W.L. van Neerven, G.J.H. Burgers.* Nucl. Phys. B297 (1988) 429.
11. *A.D. Bukin et al.* Preprint INP 84-33, Novosibirsk, 1983.
12. *S.E. Baru et al.* Z. Phys. C42 (1989) 505.
13. *R. Fulton et al.* Preprint CLNS 89/913, CLEO 89-7, 1989.

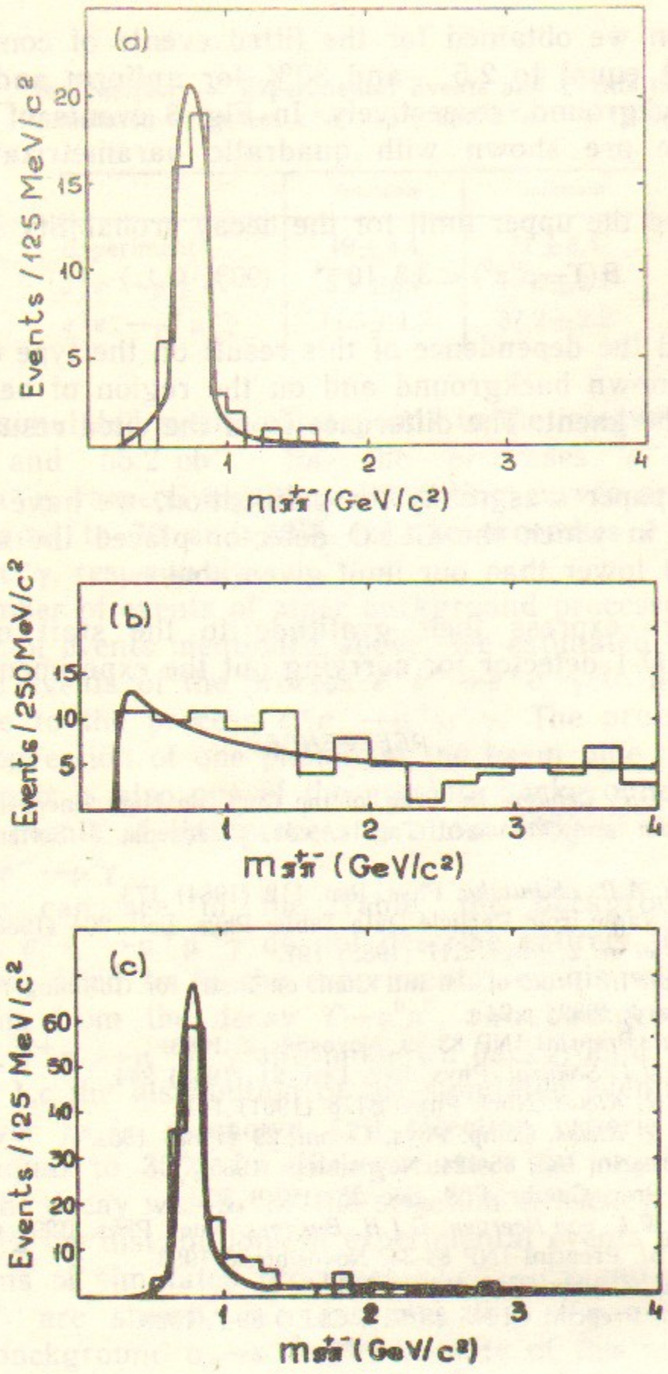

Fig. 1. Distributions of events of simulated processes $e^+e^- \to \rho^0\gamma$ (*a*); $e^+e^- \to \mu^+\mu^-\gamma$ (*b*); decay $\Upsilon \to \rho^0\pi^0$ (*c*) over the invariant mass of charged particles $m_{\pi^+\pi^-}$ and fitted curves for these processes.

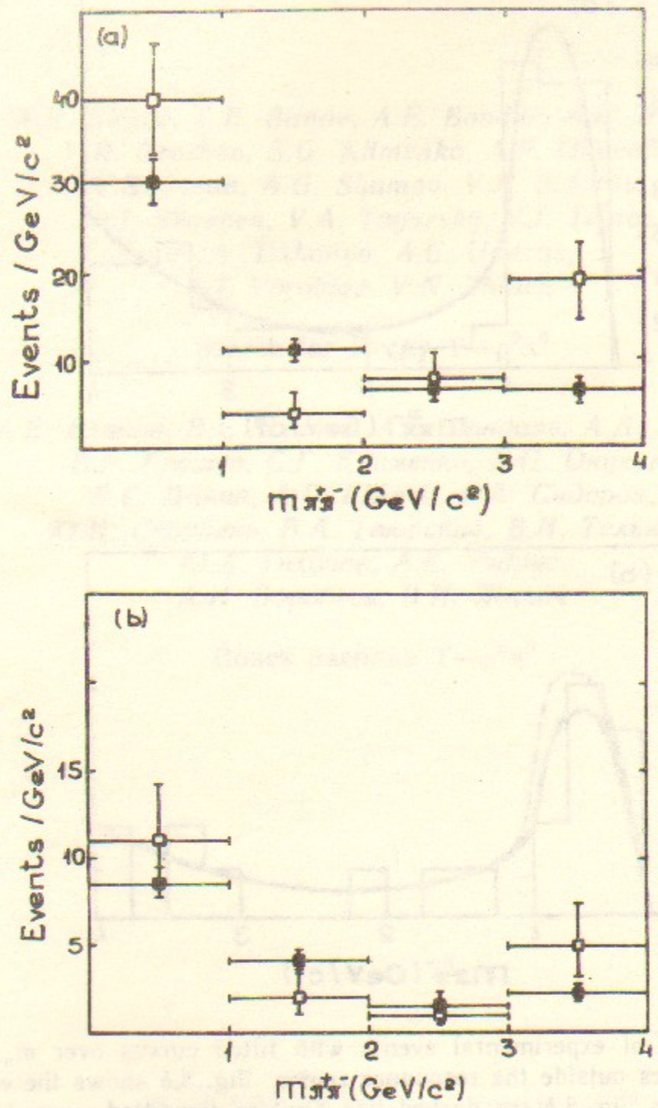

Fig. 2. Distribution of experimental (□) and simulated (■) events ($e^+e^- \to \rho^0\gamma$ and $\mu^+\mu^-\gamma$) over $m_{\pi^+\pi^-}$. Fig. 2,*a* includes the statistics out of resonance region. Fig. 2,*b* shows the events in the vicinity of the resonance.

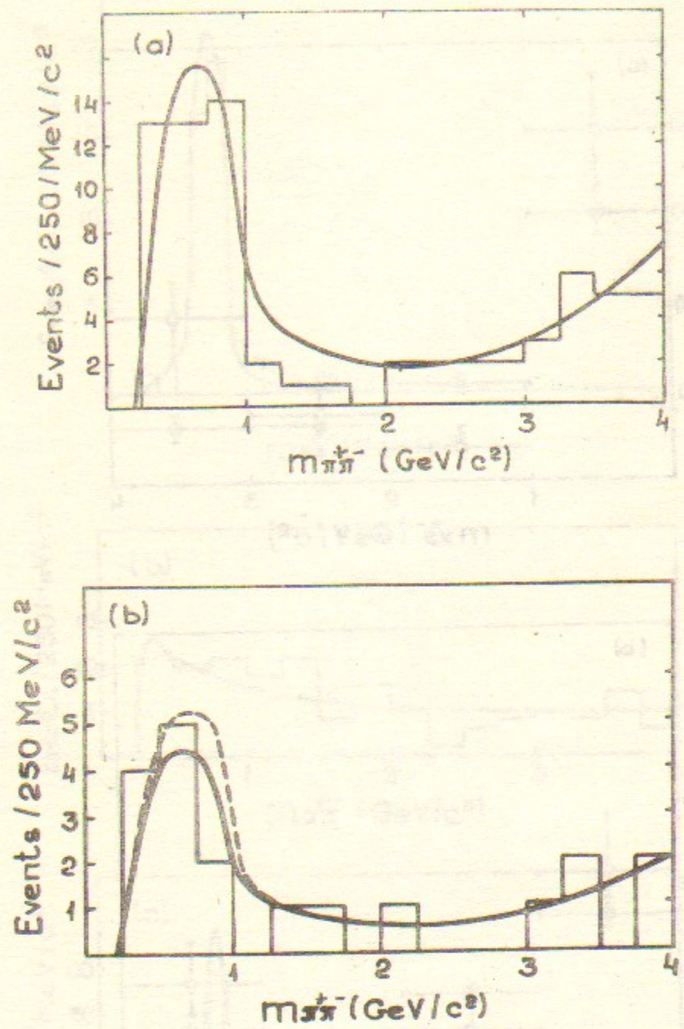

Fig. 3. Distribution of experimental events with fitted curves over $m_{\pi^+\pi^-}$. Fig. 3,*a* includes the statistics outside the resonance region. Fig. 3,*b* shows the events in the resonance region. In Fig. 3,*b* the dashed line displays the fitted curve including the decay $\Upsilon \to \rho^0\pi^0$ with a probability $B(\Upsilon \to \rho^0\pi^0) = 3.3 \cdot 10^{-4}$ in addition to the background processes.

A.E. Blinov, V.E. Blinov, A.E. Bondar, A.D. Bukin,
V.R. Groshev, S.G. Klimenko, A.P. Onuchin,
V.S. Panin, A.G. Shamov, V.A. Sidorov,
Yu.I. Skovpen, V.A. Tayursky, V.I. Telnov,
Yu.A. Tikhonov, A.E. Undrus,
A.I. Vorobiov, V.N. Zhilich

Search for Decay $\Upsilon \to \rho^0\pi^0$

А.Е. Блинов, В.Е. Блинов, А.Е. Бондарь, А.Д. Букин,
В.Р. Грошев, С.Г. Клименко, А.П. Онучин,
В.С. Панин, А.Г. Шамов, В.А. Сидоров,
Ю.И. Сковпень, В.А. Таюрский, В.И. Тельнов,
Ю.А. Тихонов, А.Е. Ундрус,
А.И. Воробьев, В.Н. Жилич

Поиск распада $\Upsilon \to \rho^0\pi^0$

Ответственный за выпуск С.Г.Попов

Работа поступила 13 марта 1990 г.
Подписано в печать 28.03 1990 г. МН 08483
Формат бумаги 60×90 1/16 Объем 1,1 печ.л., 0,9 уч.-изд.л.
Тираж 290 экз. Бесплатно. Заказ № 44

Набрано в автоматизированной системе на базе фотонаборного автомата ФА1000 и ЭВМ «Электроника» и отпечатано на ротапринте Института ядерной физики СО АН СССР,
Новосибирск, 630090, пр. академика Лаврентьева, 11.