Search for the processes $e^+e^- \to \pi^0\pi^0, \eta\pi^0$ in the energy range $2E_0 = 0.98 - 1.38\text{GeV}$

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The reactions $e^+e^- \to \pi^0\pi^0, \eta\pi^0$ were searched in the energy range 2E$_0$= 0.98—1.38 GeV by the SND detector at the VEPP-2M e^+e^- collider. No candidates for such reactions were found. The new upper limits on electron branching ratios of tensor mesons a$_2$(1320) and f$_2$(1270) were obtained at 90% confidence level: $Br(a_2(1320) \to e^+e^-) < 6 \cdot 10^{-9}$, $Br(f_2(1270) \to e^+e^-) < 6 \cdot 10^{-10}$.

1. Introduction

C-even resonances can be produced in e^+e^- collisions through two-photon intermediate state (fig. 1), although it is not easy to calculate the corresponding cross section. Nevertheless, a tensor meson electron width can be estimated in the unitary limit [1] and it appears to be connected to its two-photon width by a factor $\sim \alpha^2$ [2]. The actual value of the electron width can be even several times larger due to the real part of the amplitude, which can not be evaluated without precise knowledge of the transition form factor.

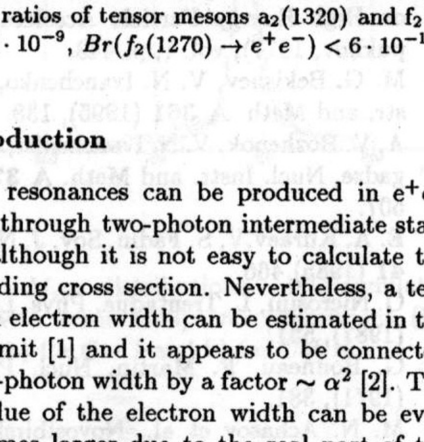

Figure 1. C-even resonance production diagram in the e^+e^- interactions.

The modern experimental data for $\Gamma_{T\to\gamma\gamma}$ [3] indicate the following unitary limits for the a$_2$(1320) and f$_2$(1270) tensor meson electron widths:

$$\Gamma_{unit.lim.}(a_2(1320) \to e^+e^-) \sim 0.01\ eV, \quad (1)$$

$$\Gamma_{unit.lim.}(f_2(1270) \to e^+e^-) \sim 0.03\ eV \quad (2)$$

The only experimental result about these electron widths was obtained at e^+e^- collider VEPP-2M with ND detector [4]. In particular, the reactions

$$e^+e^- \to a_2(1320) \to \eta\pi^0 \quad (3)$$

and

$$e^+e^- \to f_2(1270) \to \pi^0\pi^0 \quad (4)$$

with four photons in the final state were investigated [5,6]. The following upper limits were obtained at 90% confidence level:

$$\Gamma(a_2(1320) \to e^+e^-) < 25\ eV, \quad (5)$$

$$\Gamma(f_2(1270) \to e^+e^-) < 1.7\ eV \quad (6)$$

In the present work the similar analysis is repeated for much more statistics gathered by more advanced SND detector [7] at the same collider.

The cross section for the reaction (4) looks like [8]

$$\frac{d\sigma}{d\Omega}(e^+e^- \to f_2(1270) \to \pi^0\pi^0) = = 12.5 \cdot \left(\frac{2E_0}{m}\right)^6 \cdot \frac{\Gamma^2 \cdot B_{ee} \cdot B_{\pi^0\pi^0}}{(m^2-s)^2 + m^2\Gamma^2} \cdot sin^2(2\theta), \quad (7)$$

where $s = 4E_0^2$ (E_0 being the beam energy), m and Γ are the mass and full width of the $f_2(1270)$ meson. B$_{ee}$ and $B_{\pi^0\pi^0}$ are its decay branching ratios into e^+e^- and $\pi^0\pi^0$ respectively. The same formula with obvious changes holds for the process (3).

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In the unitary limit the above given formula predicts about 1 pb total cross section at $\sqrt{s}$=m$_{f_2}$ for the reaction (4). For the process (3) approximately three times smaller total cross section is expected.

2. Detector, experiment

The Spherical Neutral Detector SND [7] operates at the VEPP-2M collider since 1995. In total about 30 pb^{-1} integrated luminosity was collected in the energy range 2E$_0$= 0.4—1.4 GeV.

The main part of the SND detector is a spherical three layer electromagnetic calorimeter consisting of 1632 NaI(Tl) crystals. The solid angle coverage is 90% of 4π. The energy and angular resolutions of the calorimeter for 500 MeV photons are 5% and 1.5° respectively. Charged particle tracks are registered by two coaxial cylindrical drift chambers.

During the 1997 experiment two successful scans, up and down in energy, were performed in the energy range 2E$_0$= 0.98—1.38 GeV with the step 2ΔE$_0$= 10 MeV. This work is based on the 5.9 pb^{-1} luminosity integral accumulated during these scans. The systematic error in the luminosity measurement is estimated to be about 3%.

3. Event selection

The events with only four photons in the final state were selected to search the processes (3) and (4). The main background processes are:

$$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma, \quad (8)$$

$$e^+e^- \to 4\gamma\ (QED), \quad (9)$$

$$e^+e^- \to \omega\gamma \to \pi^0\gamma\gamma,\ \eta\gamma\gamma, \quad (10)$$

$$e^+e^- \to \phi\gamma \to \eta\gamma\gamma,\ \pi^0\gamma\gamma. \quad (11)$$

These background processes have total cross sections which are several orders of magnitude larger then for the processes under study (3) and (4). To construct the selection criteria and estimate detection efficiencies for the processes (3), (4), (8), (9), (10), (11), Monte Carlo simulation was performed with the program UNIMOD2 [9]. The following selection criteria were applied:

- $N_\gamma=4$, $N_{cp}=0$ — four-photons and no charged particles;
- $E_{tot}/2E_0 > 0.7$ — total energy deposition in the calorimeter, normalized over the center of mass energy;
- $P_{tot}/E_{tot} < 0.3$ — absolute value of the total momentum of the event, normalized over the total energy deposition;
- $\theta_\gamma > 27^o$ — minimal polar angle between the particle momentum and the beam direction in the event;
- $E_{\gamma_4} > 0.1\cdot E_0$ — normalized reconstructed energy of the "softest" photon in the event; This condition suppresses the QED background (9).
- $\zeta < 0$ — the likelihood of the hypothesis, that the observed transverse energy profile in the hitted crystals cluster of the calorimeter can be attributed to a single photon [10]; This parameter proved to be very useful to reject events with merged photons from the process (8).
- $\chi^2_E < 15$ — the parameter, describing energy-momentum balance in the event. This cut allows to reduce background from the process (8) with escaped photon.

About 700 events were selected after imposing the above listed cuts. This agrees to the expected background from the processes (8), (9), (10) and (11). For further analysis a special kinematic fit was performed assuming the specific intermediate state. χ^2 of this fit for different intermediate state hypothesis was used to create parameters ($\xi_{\omega\pi^0}$, $\xi_{\omega\pi^0\gamma}$, $\xi_{\omega\eta\gamma}$, $\xi_{\phi\eta\gamma}$, $\xi_{\phi\pi^0\gamma}$, $\xi_{\eta\pi^0}$ and $\xi_{\pi^0\pi^0}$) characterizing the corresponding processes.

To search candidate events of the process (4), the selection criteria listed above were strengthened by the following two additional cuts

- $\xi_{\omega\pi^0} > 1$ and $\xi_{\pi^0\pi^0} < 1.5$.

As a result all events were rejected by these requirements. The expected (according to the MC simulation) number of the background events is 2.1±0.7, mainly from the process (8). MC simulation indicates 18% detection efficiency for the signal events from the process (4).

Similarly, to search for the process (3), the following additional cuts were added:

- $\xi_{\omega\pi^0} > 2$, $\xi_{\eta\pi^0} < 1.5$;
- $\xi_{\omega\pi^0\gamma} > 2$, $\xi_{\omega\eta\gamma} > 1$;
- $\xi_{\omega\eta\gamma} > 1$, $\xi_{\omega\pi^0\gamma} > 1$.

After imposing these cuts no events were left again. The expected background is 3.9±1.2 events, mainly from the QED process (9). The detection efficiency of the process (3) varies in the range 3—6% and increases with energy.

4. Upper limits

Assuming no candidate events of the processes (3) and (4), the upper limits can be established as follows:

$$Br(T \to e^+e^-) < \frac{k_0}{N_{expected}} = \frac{k_0}{\int \frac{\Delta L(E)}{\Delta E} \cdot \sigma(E) \cdot \epsilon(E) dE} \quad (12)$$

Here k_0=2.3 corresponds to the Poisson upper bound at 90% confidence level for zero detected events [3], $\frac{\Delta L(E)}{\Delta E}$ is the accumulated luminosity integral in the energy range ΔE, $\sigma(E)$ is the total cross section of the process $e^+e^- \to T \to P$ P with $Br(T \to e^+e^-) = 1$, and, at last, $\epsilon(E)$ is the detection efficiency as given by the MC simulation.

The following upper limits on the $a_2(1320)$ and $f_2(1270)$ electron branching ratios were obtained by this procedure:

	ND'91 [6] (PDG'98 [3])	this work (SND'99)	the unitary limit
$Br(a_2 \to e^+e^-)$	$< 2.3 \cdot 10^{-7}$	$< 6 \cdot 10^{-9}$	$1.1 \cdot 10^{-10}$
$Br(f_2 \to e^+e^-)$	$< 9 \cdot 10^{-9}$	$< 6 \cdot 10^{-10}$	$1.6 \cdot 10^{-10}$

These results indicate the following bounds on the electron widths:

	ND'91 [6] (PDG'98 [3])	this work (SND'99)	the unitary limit
$\Gamma(a_2 \to e^+e^-)$, eV	< 25	< 0.65	0.012
$\Gamma(f_2 \to e^+e^-)$, eV	< 1.7	< 0.12	0.03

As we see, the limits on the lightest tensor meson ($a_2(1320)$ and $f_2(1270)$) electron widths are improved by 40 and 15 times respectively compared to the old ND result [6], but they are still 50 and 4 times larger than the unitary limits.

This year a new experiment at VEPP-2M with the SND detector was performed in the energy range $2E_0$= 1.0—1.4 GeV. We hope to improve our results using this new statistics.

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