Study of the processes $e^+e^- \to \pi^+\pi^-\pi^+\pi^-, \pi^+\pi^-\pi^+\pi^-\pi^0$ at VEPP-2M with SND detector

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Processes $e^+e^- \to 2\pi^+2\pi^-, 2\pi^+2\pi^-\pi^0$ were studied with SND detector at VEPP-2M collider in the energy range 1.0 – 1.4 GeV using total luminosity $6.2 pb^{-1}$.

1. Introduction

Processes of e^+e^--annihilation into pions attract attention due to the following reasons. First, in the $2E_0 = 1 \div 2\ GeV$ energy region these processes dominate and determine the main part of the hadronic contributions into the anomalous magnetic moment of muon and into QCD sum rules.

The $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$, $e^+e^- \to \pi^+\pi^-\pi^+\pi^-\pi^0$ processes are an important source of information for hadron spectroscopy, in particular, for study ρ-meson radial excitations. According to the existing data, in the $2E_0 = 1 \div 2\ GeV$ energy region there exist two radial excitations of the ρ meson: $\rho(1450)$ and $\rho(1700)$ [1]. Determination of parameters of these states and their interference with the ρ meson, can be found, for example, in work [2], [3]. A possible mixing of these excited ρ-states with the exotic ones (for example, 4-quark states) is discussed in [4],[5]. Recently some experimental evidence appeared in favor of $\rho_x(1300)$ state existence [6], which possibly is not a conventional quark-antiquark meson [7].

In the past these processes were studied at VEPP-2M [8–10,12], DCI[13], ADONE[14] e^+e^- colliders. Statistical accuracy achieved in these experiments is $\sim 5\%$, with a systematic error of $\sim 15\%$, and the discrepancy between different experiments is sometimes as large as $\sim 20\%$ [8,10]. Therefore, measurements with smaller systematic errors are needed to clarify situation with multi-hadron production.

2. The $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ process.

The detector description one can find in [15].

To select events of the process $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ the following "soft" selection criteria were applied:

- number of charge particles ≥ 4; number of neutral particles ≥ 0,

- number of hited wires in the first drift chamber < 30;

- energy deposition divided by beams energy< 0.8;

- likelihood function of the kinematic reconstruction < 1000

The detection efficiency was determined from the $e^+e^- \to a_1\pi \to \rho\pi\pi \to 4\pi$ simulation [11] (fig. 1). The mesured cross-section shown on fig. 2. The following sources of systematic errors were taken into account: charged particles reconstruction errors, systematic errors caused by the use of the selection cuts, i.g. cuts on the recalculated trigger and the number of hit wires, inaccuracy in luminosity determination. As a result, the systematic error was estimated as $\sim 10\%$. For the pions energy determination the procedure of the kinematic reconstruction was used. Th two-pion invariant mass distribution obtained in the following "hard" selection criteria shown in fig. 3, the distribution for the simulation events for the a_1 and Lorenz-invariant phase space simulation (LIPS) are showed.

- "soft" selection criteria

- number of neutral particles = 0

- the minimal pions energy > 175 MeV (fig. /refp4cemin)

3. The $e^+e^- \to \pi^+\pi^-\pi^+\pi^-\pi^0$ process (preliminary).

To select events of the process $e^+e^- \to \pi^+\pi^-\pi^+\pi^-\pi^0$ the following selection criteria were applied:
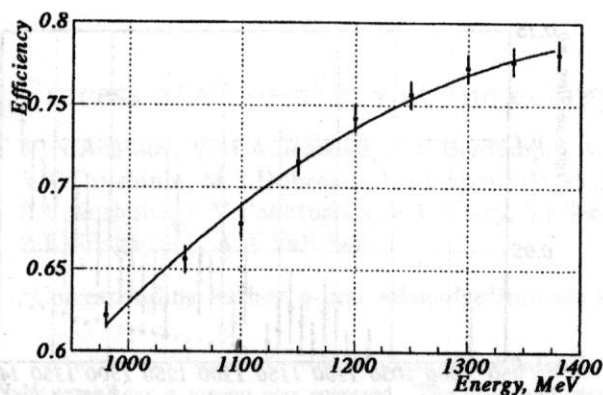
Figure 1. The efficiency dependence from the energy in the "soft" selection criteria.
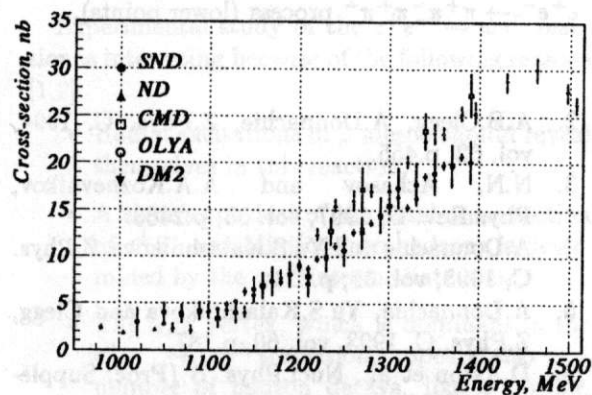

Figure 2.   Cross-section of the $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ process.
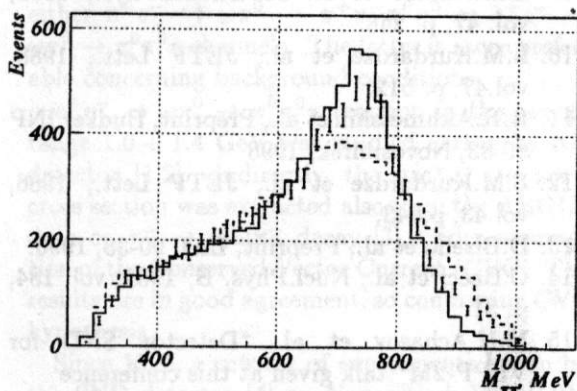

Figure 3. The distribution of the invariant mass of $\pi\pi$ system (the pion with minimal energy was rejected). Two beams energy = 1380 MeV. Dashed line — LIPS simulation; solid line a_1 simulation; circles with errors bars — experimental data.
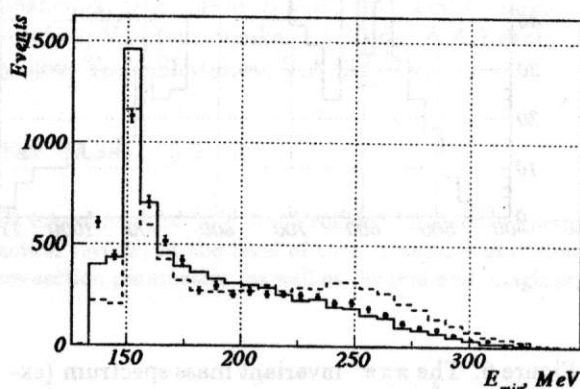

Figure 4. The distribution of the minimal pion energy. Two beams energy = 1380 MeV. Solid line — LIPS simulation; dashed line — a_1 simulation; circles with errors bars — experimental data.
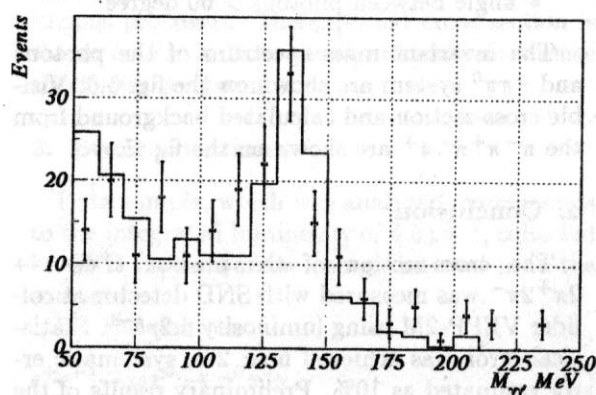

Figure 5.   Two photons invariant mass spectrum. Circles with errors bars — experimental data, solid line — the sum of the simulation $\eta\pi^+\pi^-$ (50%) and $\pi^+\pi^-\pi^+\pi^-$ (50%).
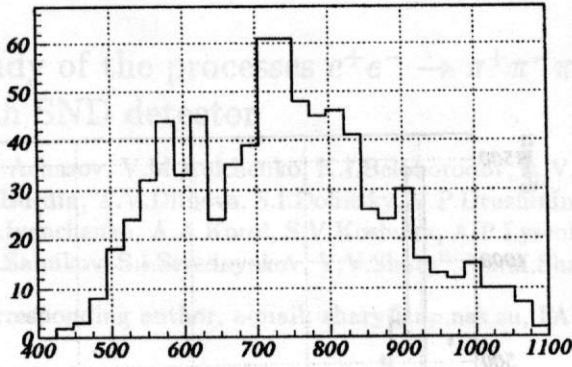
Figure 6. The $\pi\pi\pi^0$ invariant mass spectrum (experimental data).
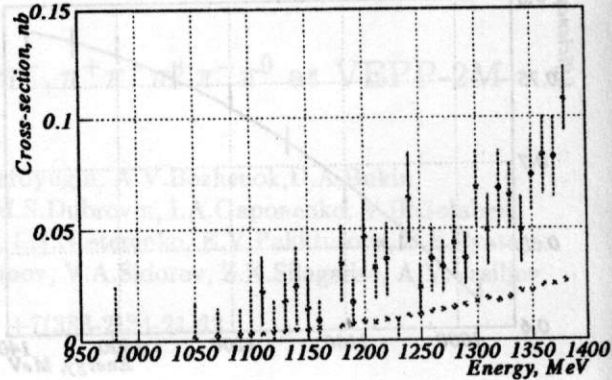

Figure 7. The $e^+e^- \to \pi^+\pi^-\pi^+\pi^-\pi^0$ visible cross-section and calculated background from the $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ process (lower points).

- number of charge particles ≥ 4; number of neutral particles ≥ 2
- number of hited wires in the first drift chamber < 30;
- energy deposition divided by beams energy < 0.8;
- likelihood function of the kinematic reconstruction (π^0 was not required) < 100
- polar angles of the photons between $45-135$ degree
- angle between photons > 60 degree

The invariant mass spectrum of the photons and $\pi\pi\pi^0$ system are shown on the fig. 5,6. Visible cross-section and calculated background from the $\pi^-\pi^+\pi^-\pi^+$ are shown on the fig. 7

4. Conclusion

The cross-section of the process $e^+e- \to 2\pi^+2\pi^-$ was measured with SND detector at collider VEPP-2M using luminosity $6.2pb^{-1}$. Statistical error was achieved near 2%, systematic error estimated as 10%. Preliminary results of the $e^+e- \to 2\pi^+2\pi^-\pi^0$ process study were reported.

5. Acknowledgment

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