A resonant contribution of I=2 amplitude into the cross section of exclusive 4 pions production in $\gamma\gamma$ collisions

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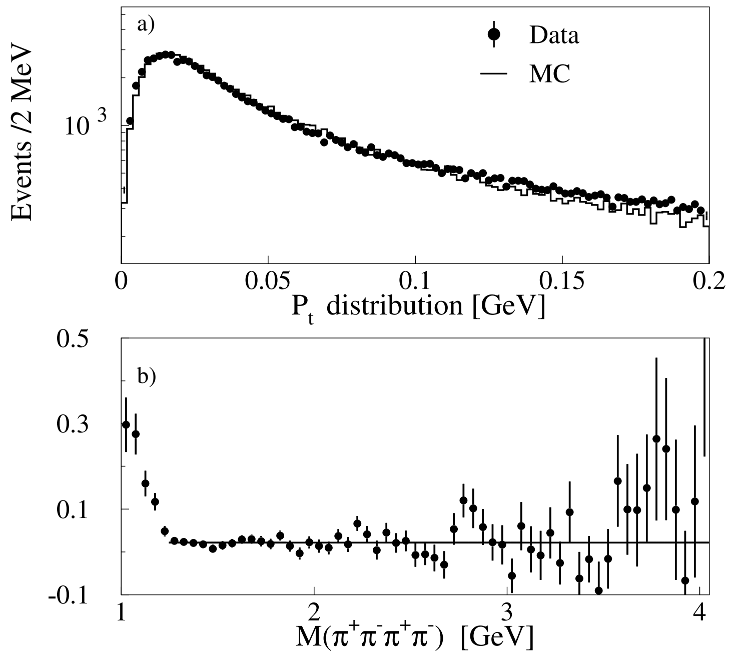
L3 data on $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ and $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ reactions

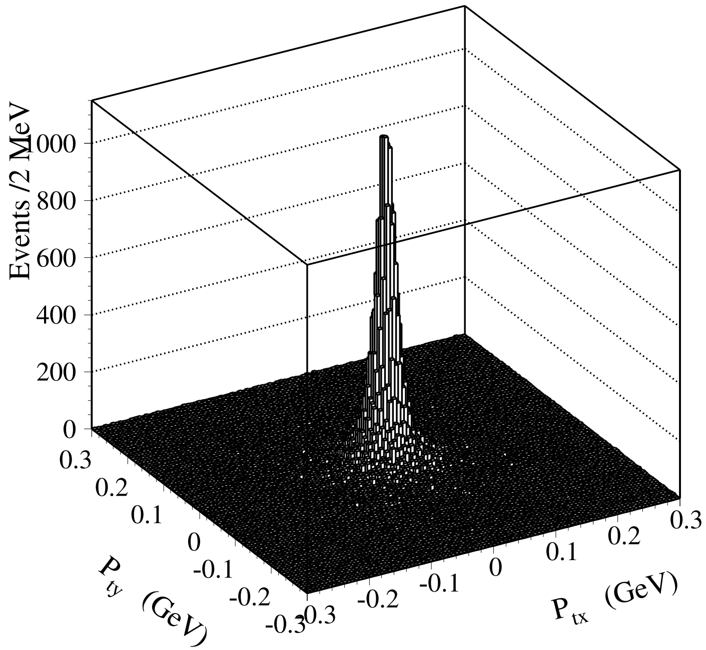
Large event sample of the reactions $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ (70000 events) and $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ (6400 events) was collected by the L3 experiment during LEP-2 runs : statistics is 5-10 times higher than in the best previous experiment (ARGUS).

There is very small background



a) The Pt distribution - data and MC for the $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ reaction;

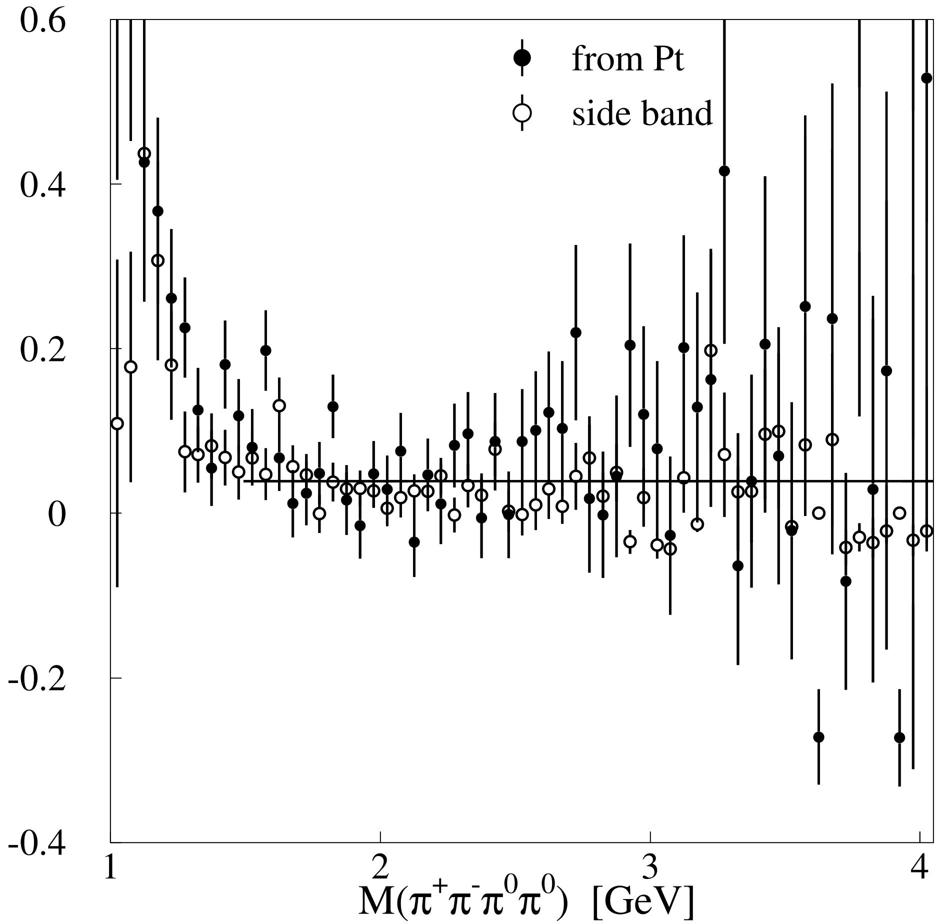
b) Background estimation. The solid line is the fit result with a constant value of $(2.0 \pm .2)$ %.



Pty vs Ptx distribution in the reaction $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$

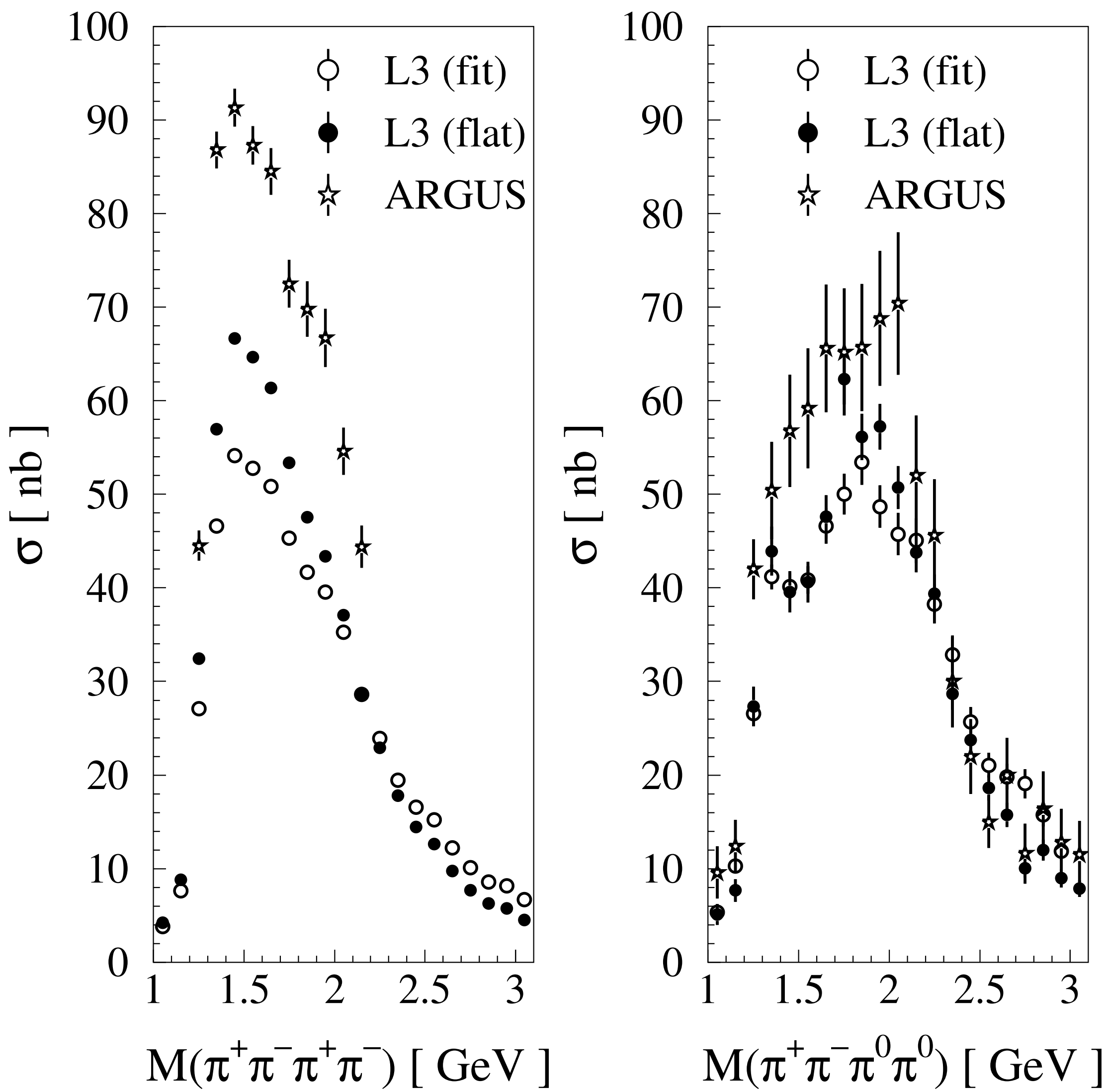
In the case of $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ reactions there are two independent methods of the estimation of background level. The same result gives a confidence.

The background level, estimated in $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ reaction from the P_t distribution (full points) and from π^0 mass distribution side bands (open points). The solid line is the fit result with a constant value of $(3.9 \pm .9)$ %.



Trigger efficiencies are determined from the data, an acceptance together with detector effects are found from MC. The shape of the cross-sections estimated by means of phase space MC are in rather good agreement with ARGUS results.

However the L3 cross section for $\gamma\gamma \rightarrow \pi^+\pi^-\pi^+\pi^-$ is much smaller.

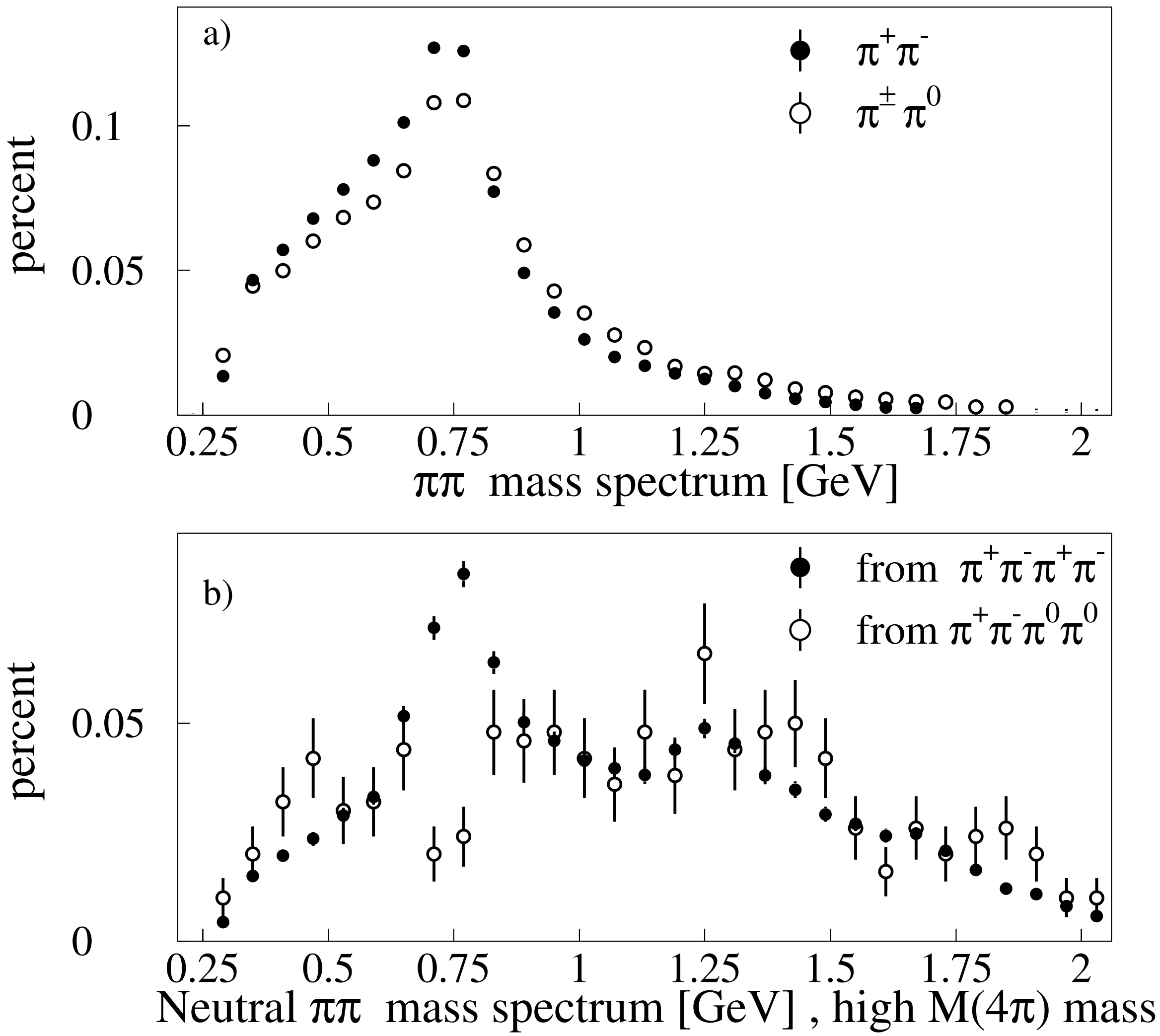


Two pion mass projections from the $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ and $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ data.

a) whole sample

b) 4 pion mass in the interval 2.4-3.0 GeV.

(All pictures normalized to the total content equal to 1.)



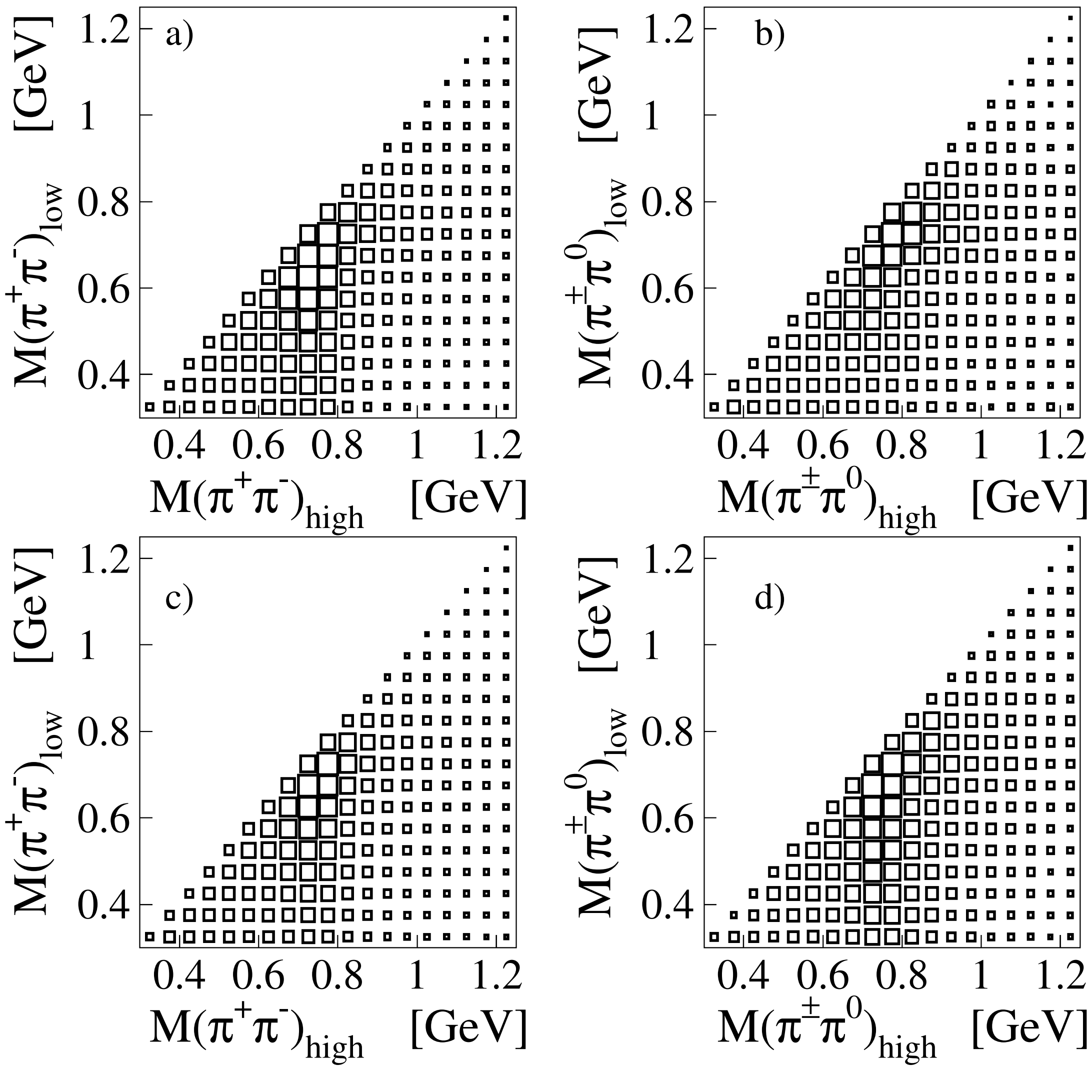
The two pion mass correlation

a) $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$

b) $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$

c) and d) the same as for a) and b) but in pairs

one of the pions is the same



Isotopic relations for decay of Isospin 0 state:

$$\frac{\sigma(\rho^+\rho^- \to \pi^+\pi^-\pi^0\pi^0)}{\sigma(\rho^0\rho^0 \to \pi^+\pi^-\pi^+\pi^-)} = 2 \qquad \frac{\sigma(f_0 f_0 \to \pi^+\pi^-\pi^0\pi^0)}{\sigma(f_0 f_0 \to \pi^+\pi^-\pi^+\pi^-)} = \frac{1}{2}$$

In a cascade reactions the correlations are important, but:

$$\frac{\sigma(a_1(\rho\pi)\pi \to \pi^+\pi^-\pi^0\pi^0)}{\sigma(a_1(\rho\pi)\pi \to \pi^+\pi^-\pi^+\pi^-)} \sim 2$$

However for the broad f_0 ($\pi\pi$ S-wave) due to correlations the ratio might be:

$$\frac{\sigma(f_0 f_0 \to \pi^+\pi^-\pi^+\pi^-)}{\sigma(f_0 f_0 \to \pi^+\pi^-\pi^0\pi^0)} \to \frac{1}{4} \qquad \frac{\sigma(a_1(f_0\pi)\pi \to \pi^+\pi^-\pi^+\pi^-)}{\sigma(a_1(f_0\pi)\pi \to \pi^+\pi^-\pi^0\pi^0)} \to 1$$

The partial contributions to the total cross-section STRONGLY depend on the subprocess composition.

In previous analysis very simple models has been checked.

Only 3 subprocesses have been considered:

1) 4π - phase space contribution;

2) $\rho + 2\pi$ - single ρ production;

3) 2ρ mesons in the final state.

Only for the last subprocess partial wave decomposition was applied.

The main conclusion of all previous publications: There is a strong deviation from the isospin relations for initial Isospin 0 production of the 2ρ meson final states. Most exciting explanation of such phenomenon:

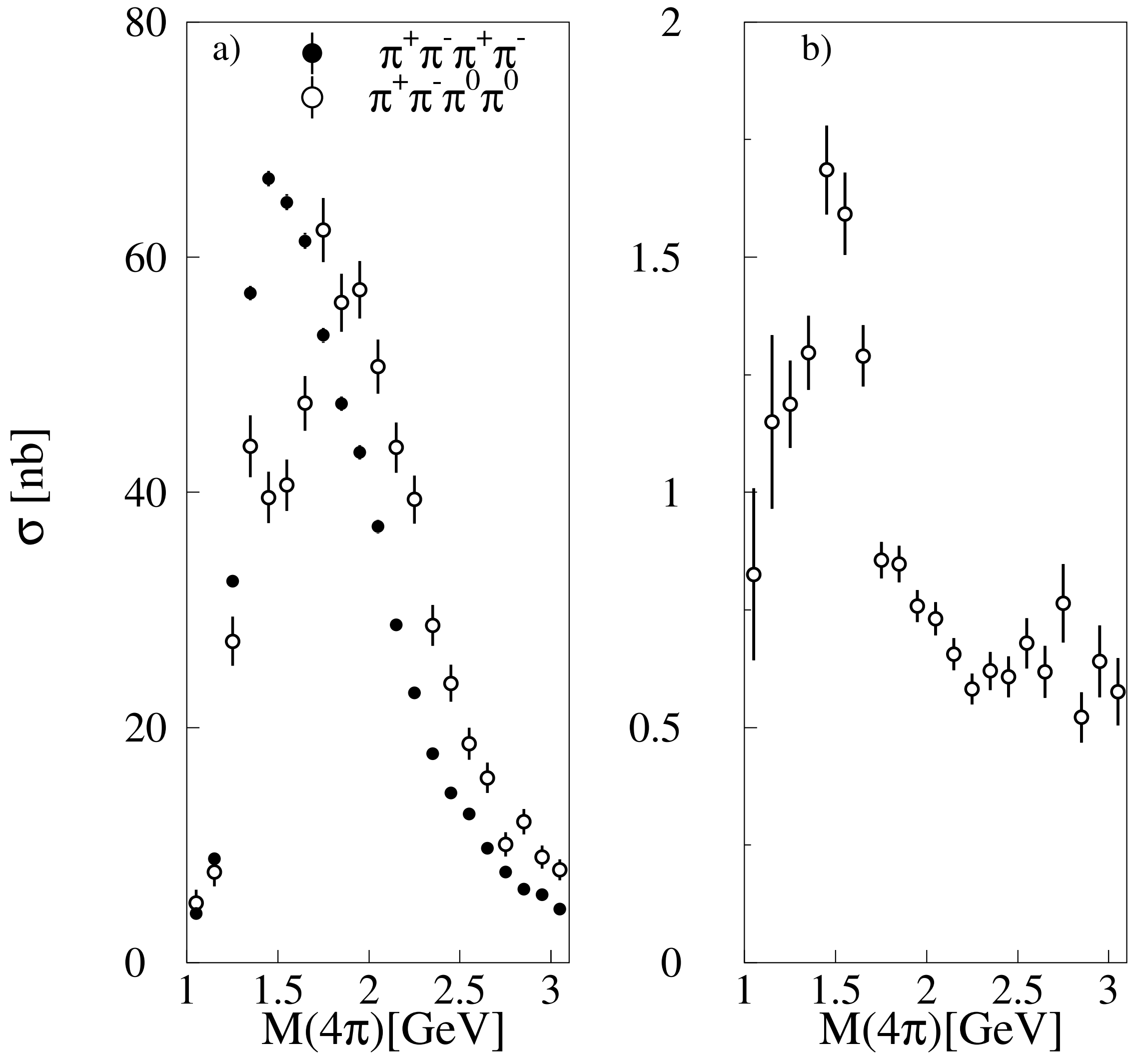
A production of Quadroquark in $\gamma\gamma$- collision

The ratio of estimated total cross sections for $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ **and** $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ **reactions has quite complicated behaviour.**

a)$\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ **(full points)**

$\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ **(open points);**

b) The ratio of the cross sections $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ **and** $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ **.**



Partial Wave Analysis

Only Partial Wave Analysis (PWA) provides detailed information on the final state subprocesses. The estimation of a subprocess cross-section requires rather good identification of these subprocess.

1) The transition $\gamma\gamma$ into:

a) $X(2\pi)X(2\pi)$

b) $Y(3\pi)\pi \to X(2\pi)\pi\pi$

2) All interferences in $\gamma\gamma \to mesons$ cross section are taken into account.

3) We performed a free fit and fits with isotopic relations directly imposed in the combined analysis of two reactions.

In present analysis we included:

In 2π channel: $\rho(770)$, f_0 **(**$\pi\pi S - wave$**)**, $f_2(1275)$.

In 3π channel: $a_1(1260)$, $\pi(1350)$, $a_2(1320)$

We also investigated: $\rho(1450)$, $a_2(1700)$, $\pi_1(1400)$

Large statistics of the $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ channel gives the possibility to perform the detailed analysis.

Energy independent approach is used with the $M_{\gamma\gamma}$ slices of 200 MeV. All not forbidden interference effects are included. Up to 25 statistically significant parameters are found.

Moderate statistics in $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ channel is just enough to find out the contribution of subprocesses in a separate analysis.

The isospin invariance give the possibility to draw any distribution for the $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ reaction from the analysis result of $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ process and compare with the measured one.

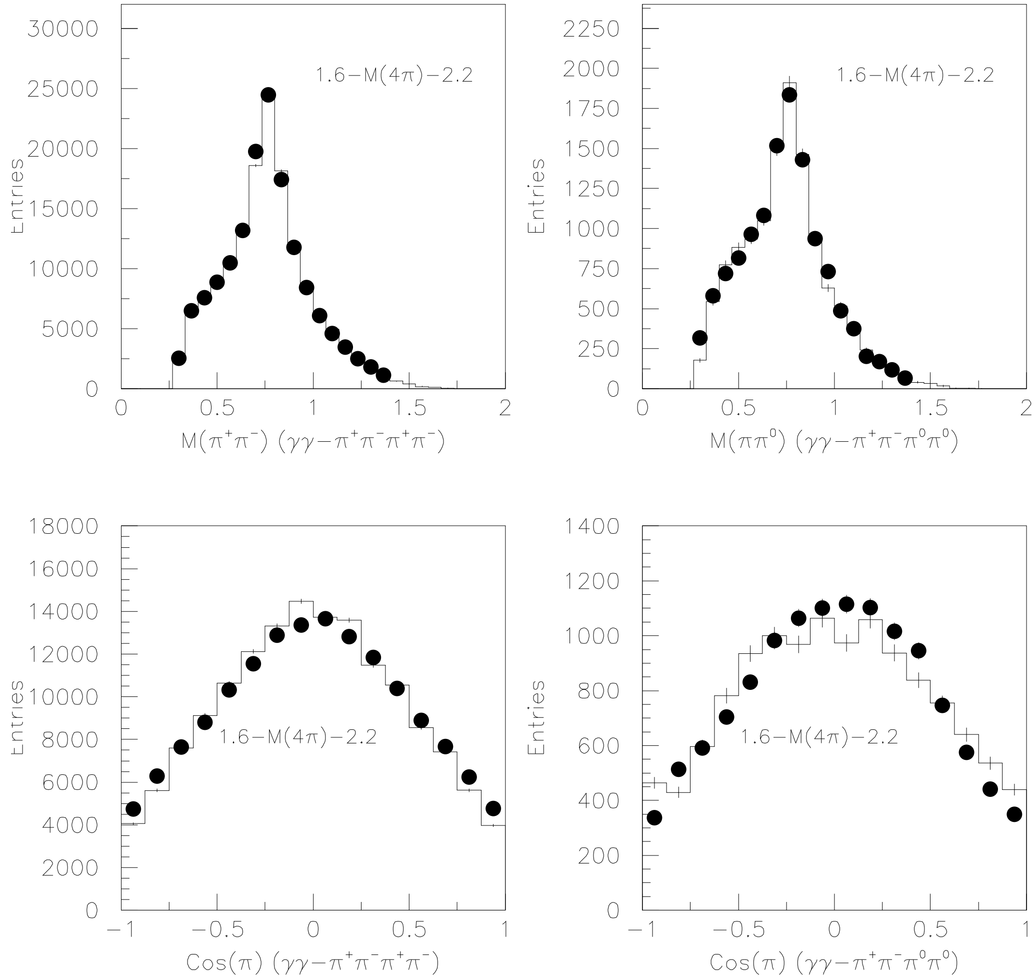
The following assumptions had been checked:

1. **Isotopic relations hint to some trivial explanation of the total cross sections: at the energy region below $\rho\rho$ threshold the dominant decays are into isoscalar systems. However...**
   No satisfactory description of the of the energy region below 1.6 GeV was found under such assumptions.

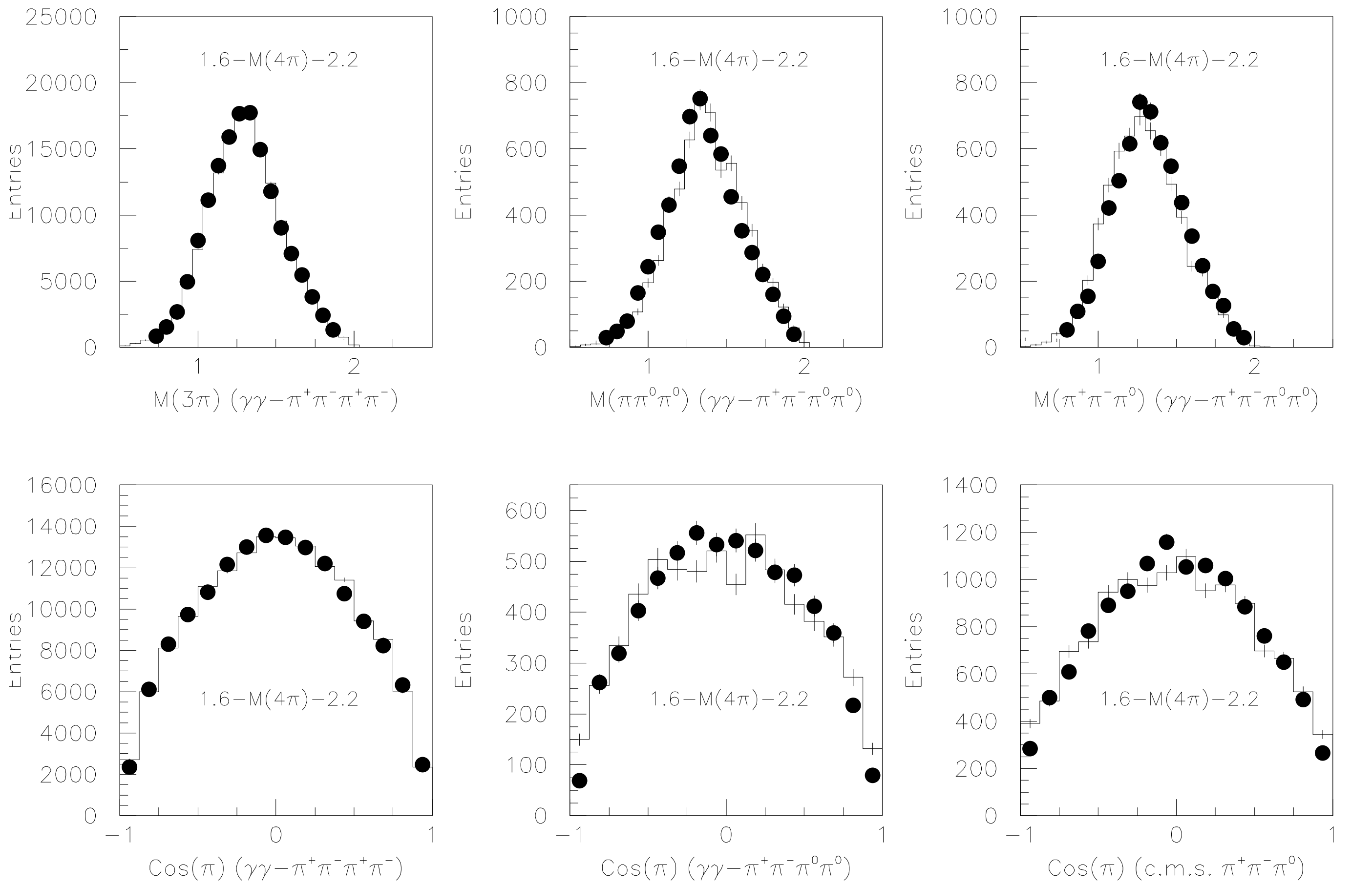
2. **Fit with isotopic relations for isospin 0 explicitly imposed:**
   Again: no satisfactory description of the of the two pion mass and angular distributions.

3. **A decay at least into one ρ-meson (for example from $a_1(1240)$ or $\pi(1300)$) is needed already at very low energies.**

Energy independent analysis: $a_1(1260)\pi$, $\pi(1300)\pi$, $\rho(770)\rho(770)$ and $a_2(1320)$ at high $\gamma\gamma$ invariant masses.

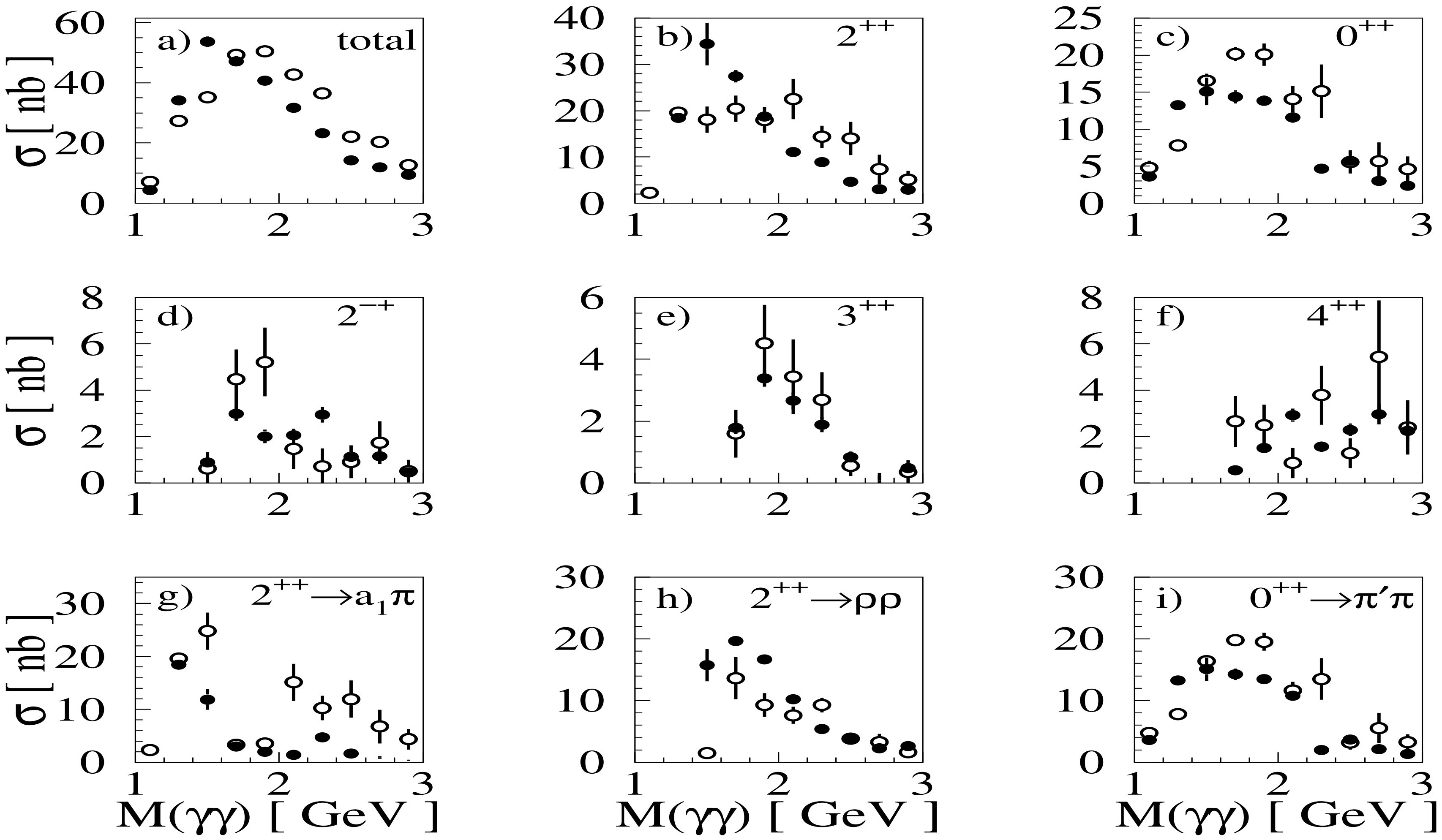


Two pion mass distributions and angular distribution of charged pion in c.m.s. of this pion and another pion in channels where $\rho(770)$ production is allowed.

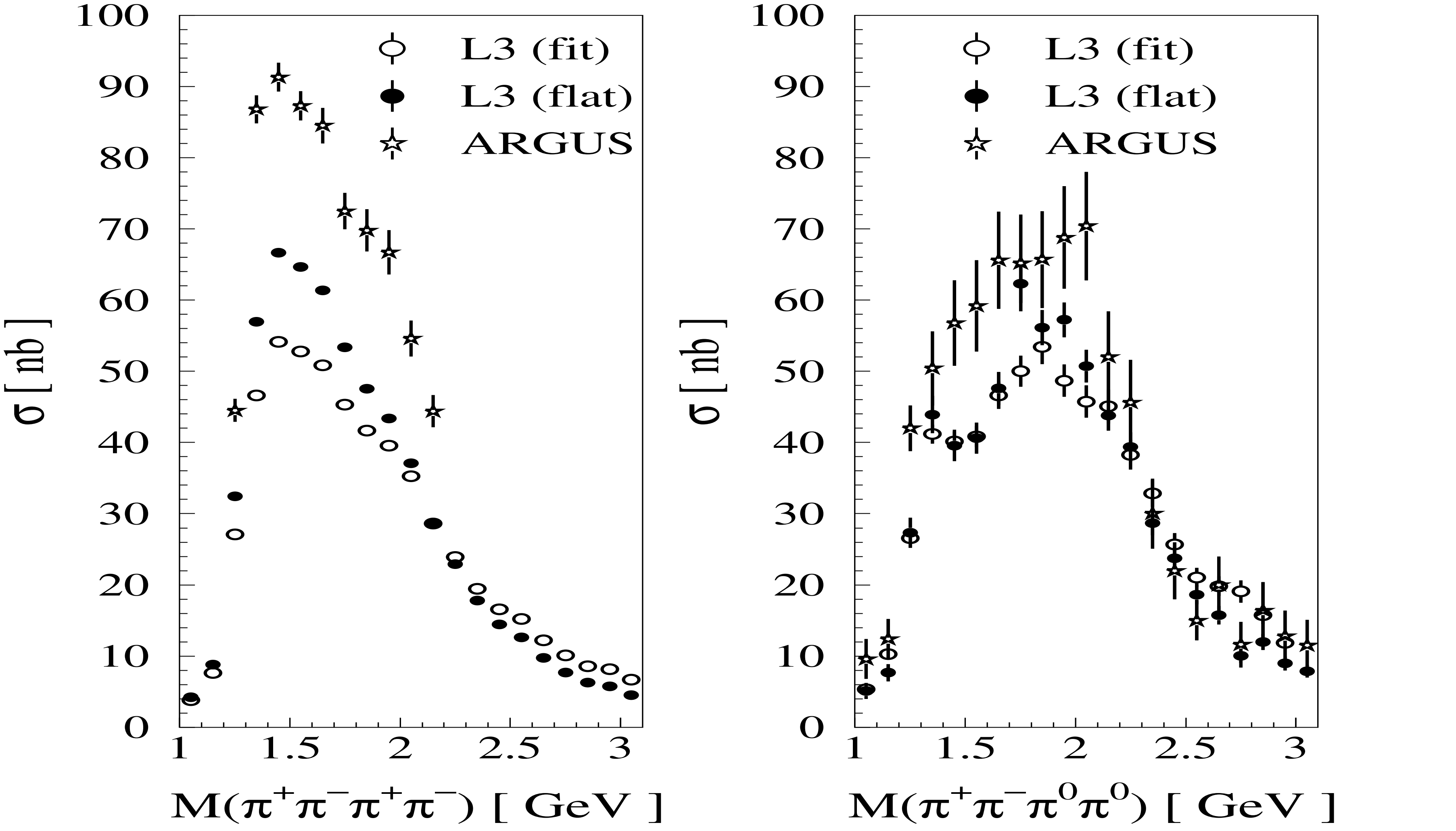


Three pion mass distributions and angular distributions of pions in c.m.s. of $\gamma\gamma$ system.

The calculated cross section of subprocesses.

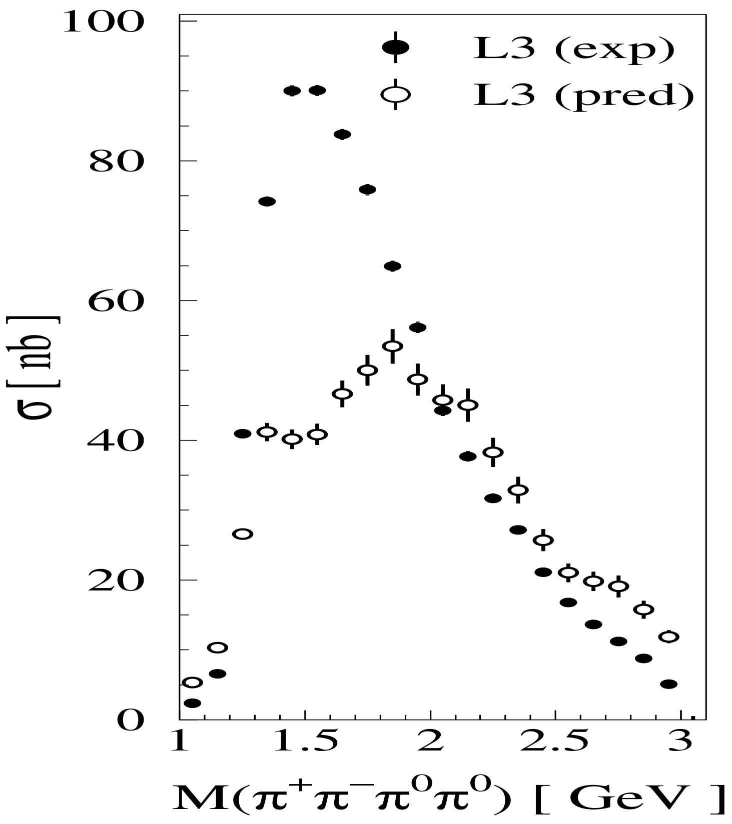


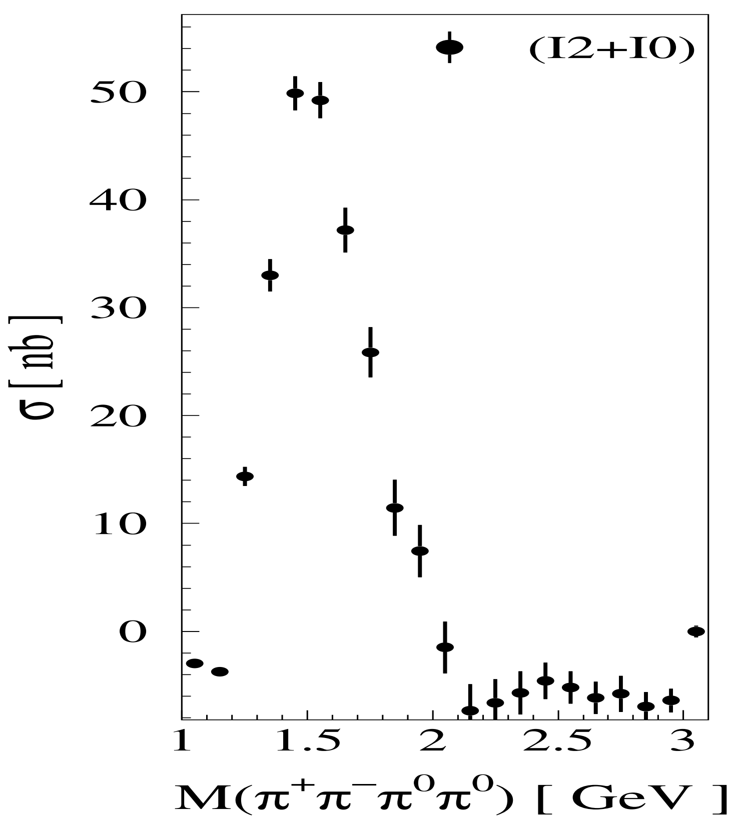
The corrected total cross-sections for the reactions $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ and $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$



Contribution of isospin 2 :a) The cross section of $\gamma\gamma \rightarrow \pi^+\pi^-\pi^0\pi^0$ reaction-measured (open points) and calculated from PWA (black points);

b) the difference between two estimates





Summary

1. **The analysis of the $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ and $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ reactions have been performed in the framework of energy independent partial wave analysis.**

2. **The contribution from three pion intermediate resonances was found to be dominant below $\rho\rho$ threshold.**

3. **No possibilities to obtain a satisfactory description of the data under assumption about pure isospin 0 initial state. We observed:**
   a strong resonant like deviation between found and predicted cross sections for $\gamma\gamma \to \pi^+\pi^-\pi^0\pi^0$ reaction.

4. **This is either an indication of an exotic isospin 2 resonance(s) or an interference effect between an isospin 0 resonance and a nonresonant isotensor wave.**