Formation of Light Resonances in LEP II $\gamma\gamma$ collisions ($\sqrt{s} = 160 - 189$ GeV)

L3 collaboration

Igor Vodopianov

Petersburg Nuclear Physics Institute
Gatchina, 188350 St. Petersburg, Russia

23 – 27 May 1999

International Conference
on the Structure and Interactions of the Photon

PHOTON 99
Freiburg, Germany

- Introduction
- Resonances in $\mathrm{K^0_S\,K^{\pm}}\pi^{\mp}$ spectrum at 1.44 GeV
  - Resonance(s) yield
  - Form factor study
  - Decay modes
- Conclusion

Hadronic Resonances Studied by L3 at LEP

Hadronic Resonances Studied by L3 at LEP-1 are listed in Table 1. Results are published.

Table 1

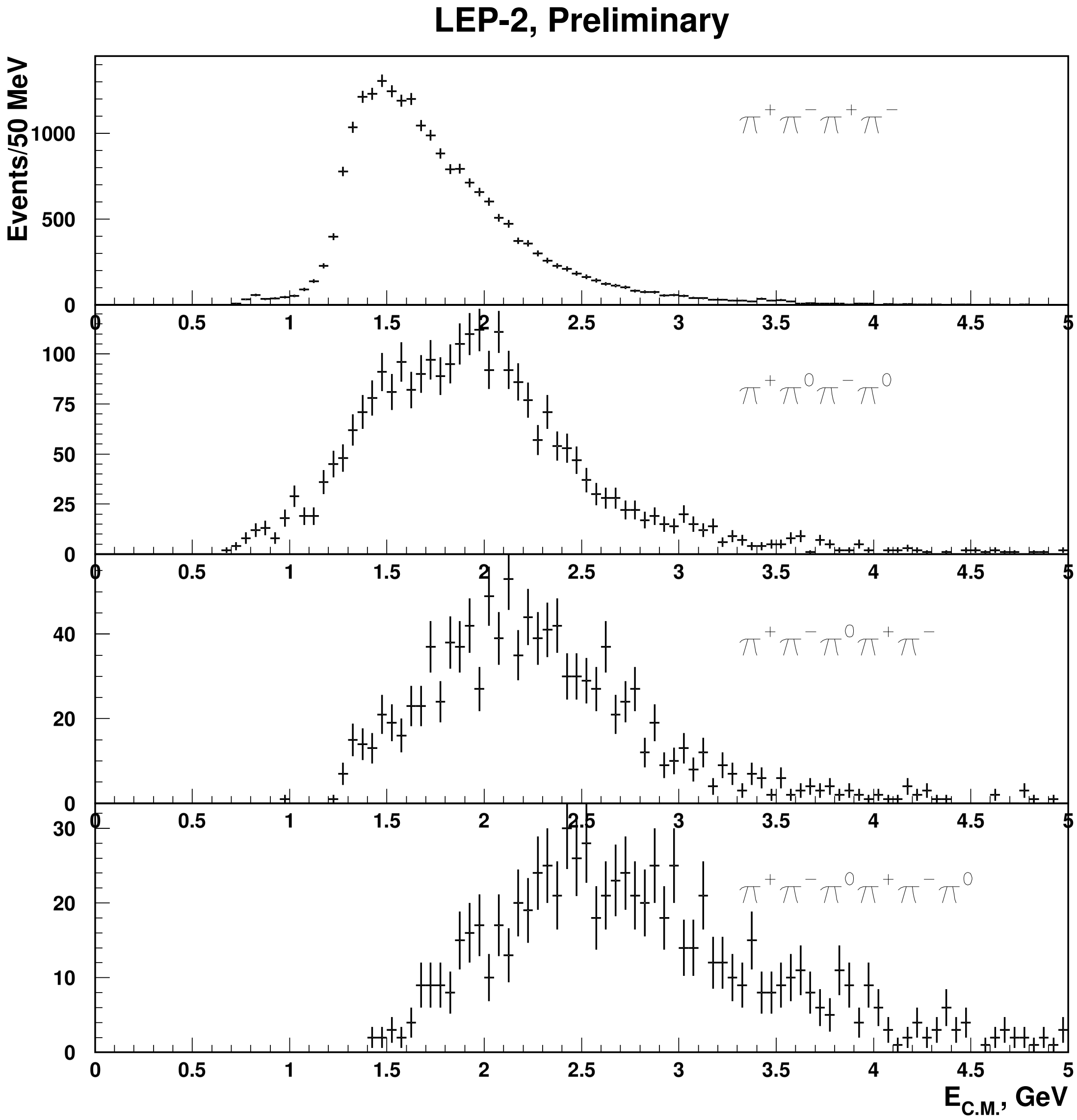
Resonance	final state	J^{PC}	$\Gamma_{\gamma\gamma}(keV)$
1. $\eta'(958)$	$\pi^+\pi^-\gamma$	0^{-+}	4.17±0.10±0.27
2. $a_2(1320)$	$\pi^+\pi^-\pi^0$	2^{++}	0.98±0.05±0.09
2. $a_2'(1752)$	$\pi^+\pi^-\pi^0$	2^{++}	0.29*±0.04±0.02
3. $f_2'(1525)$	$K_s^0K_s^0$	2^{++}	0.085*±0.03
3. X(1770)	$K_s^0K_s^0$	0^{++}	
4. $\eta_c(2980)$	10 chan.	0^{-+}	9.5±2.±2.7
5. $\chi_{c2}(3555)$	$l^+l^-\gamma$	2^{++}	1.02±0.4±0.15±0.09

$^\star\Gamma_{\gamma\gamma} \times BR$

1. Phys.Lett. B418 (1998) 399
2. Phys.Lett. B413 (1997) 147
3. Phys.Lett. B363 (1995) 118 and L3 Note 2285 (June 1998)
4. Phys.Lett. B318 (1993) 575 and L3 Note 2297 (July 1998)
5. CERN-EP/98-184

Multi-Pion States Exclusive Production

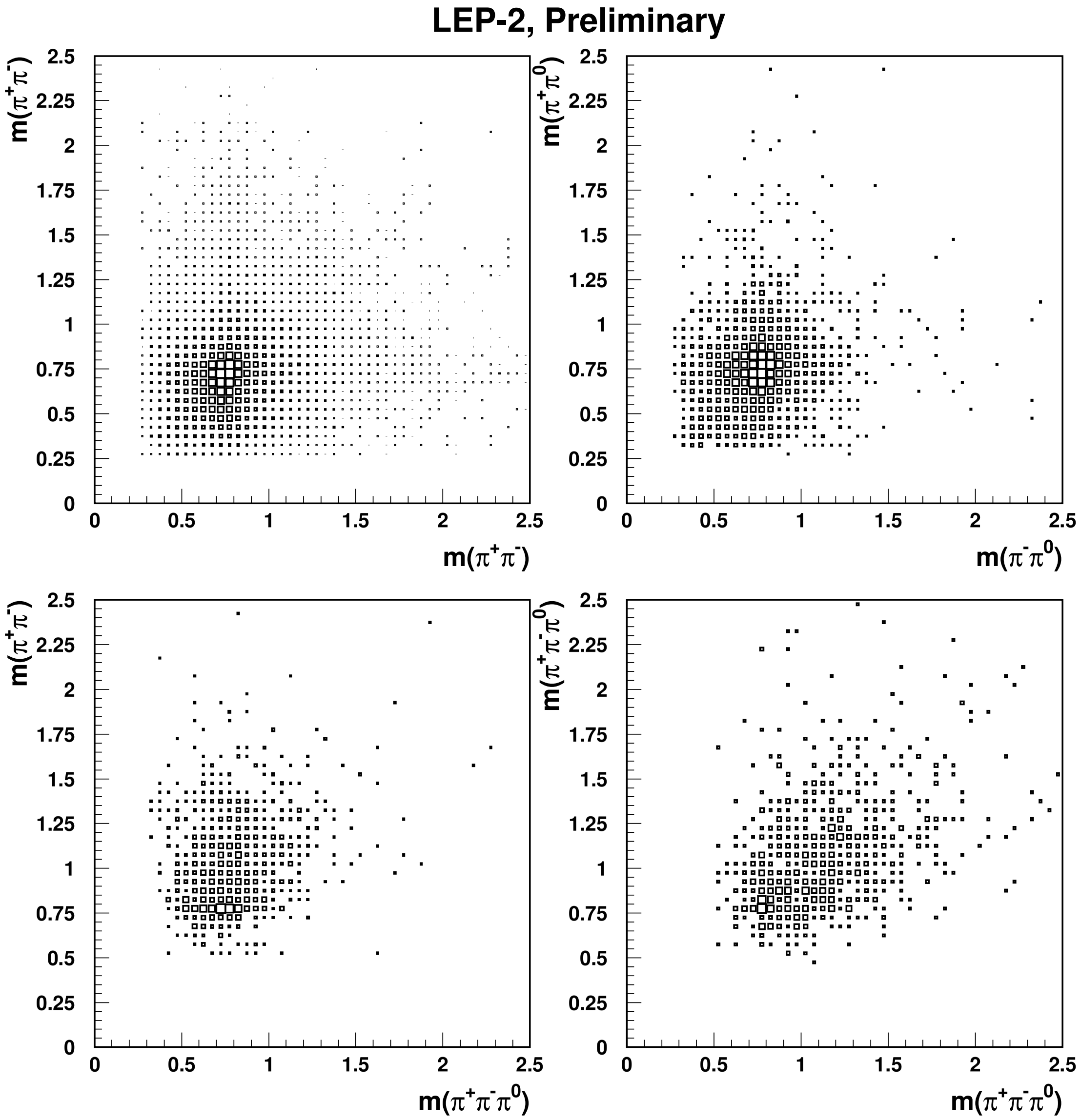
Rather large integrated luminosity of LEP-2 opens the opportunities for a high-statistics study of the $\gamma\gamma$-interaction. A first look to LEP-2 data clearly demonstrate this.



These states are strongly connected to the vector meson production. Measurement of the exclusive production of vector mesons is of a special interest because of the high probability of photons to fluctuate into neutral vector mesons. The Vector Dominance Model (VDM) is an important ingredient of all models of $\gamma\gamma$-interactions, and a thorough check of its predictions would play a fundamental role.

Mass Correlations

The dominant process in the exclusive production of vector mesons, having quite high cross-section, is the $\rho^0\rho^0$ * production. The final states with $\rho^0\omega$, $\omega\omega$, or $\rho^+\rho^-$ are produced with much lower cross-sections, and it is only after the LEP-2 data became available that a reasonable analysis of these states is feasible.



* See report of A.Csilling (Photon99)

I will concentrate my talk

on the $\mathrm{K^0_S}\,\mathrm{K}^{\pm}\pi^{\mp}$ channel

All results are preliminary !

PDG: resonances around 1.44 GeV in $K^0_S K^{\pm}\pi^{\mp}$ spectrum

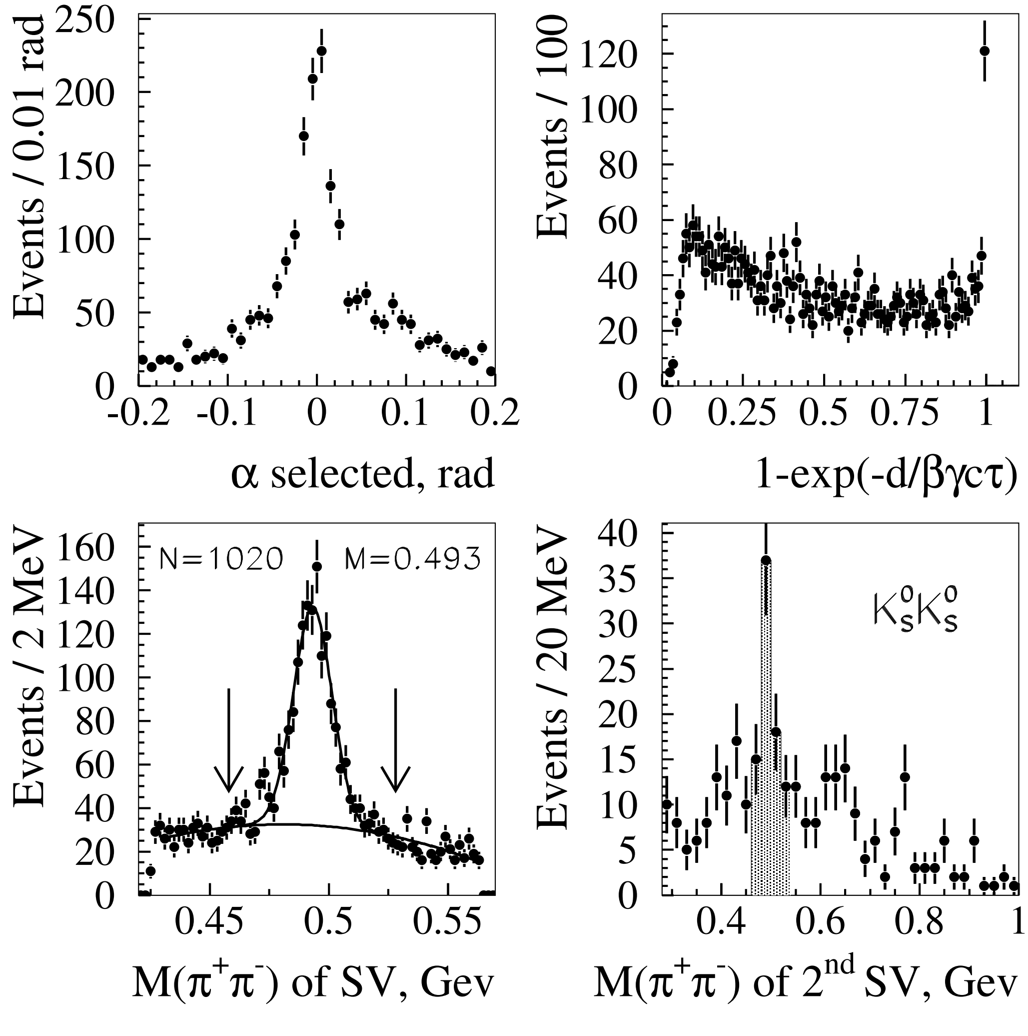
Table 2

Resonance	$f_1(1420)$	$\eta(1440)$	$f_1(1510)$
$I^G(J^{PC})$	$0^+(1^{++})$	$0^+(0^{-+})$	$0^+(1^{++})$
Mass, MeV	1426.2 ± 1.2	$1400 — 1470$	1518 ± 5
Width, MeV	55 ± 3.0	$50 — 80$	73 ± 25
Seen in	$\pi p, p\bar{p}, Kp, J/\psi - decay$	$\pi p, p\bar{p}, J/\psi - decay$	$\pi p, Kp$
Seen in $\gamma\gamma$?	$\gamma^*\gamma^*$ TPC-2 , $\gamma^*\gamma$ CELLO	no	no
Decay modes	$K\bar{K}^*(892) + c.c.$ dominant	$K\bar{K}^*(892) + c.c.$ $a_0(980)\pi$	

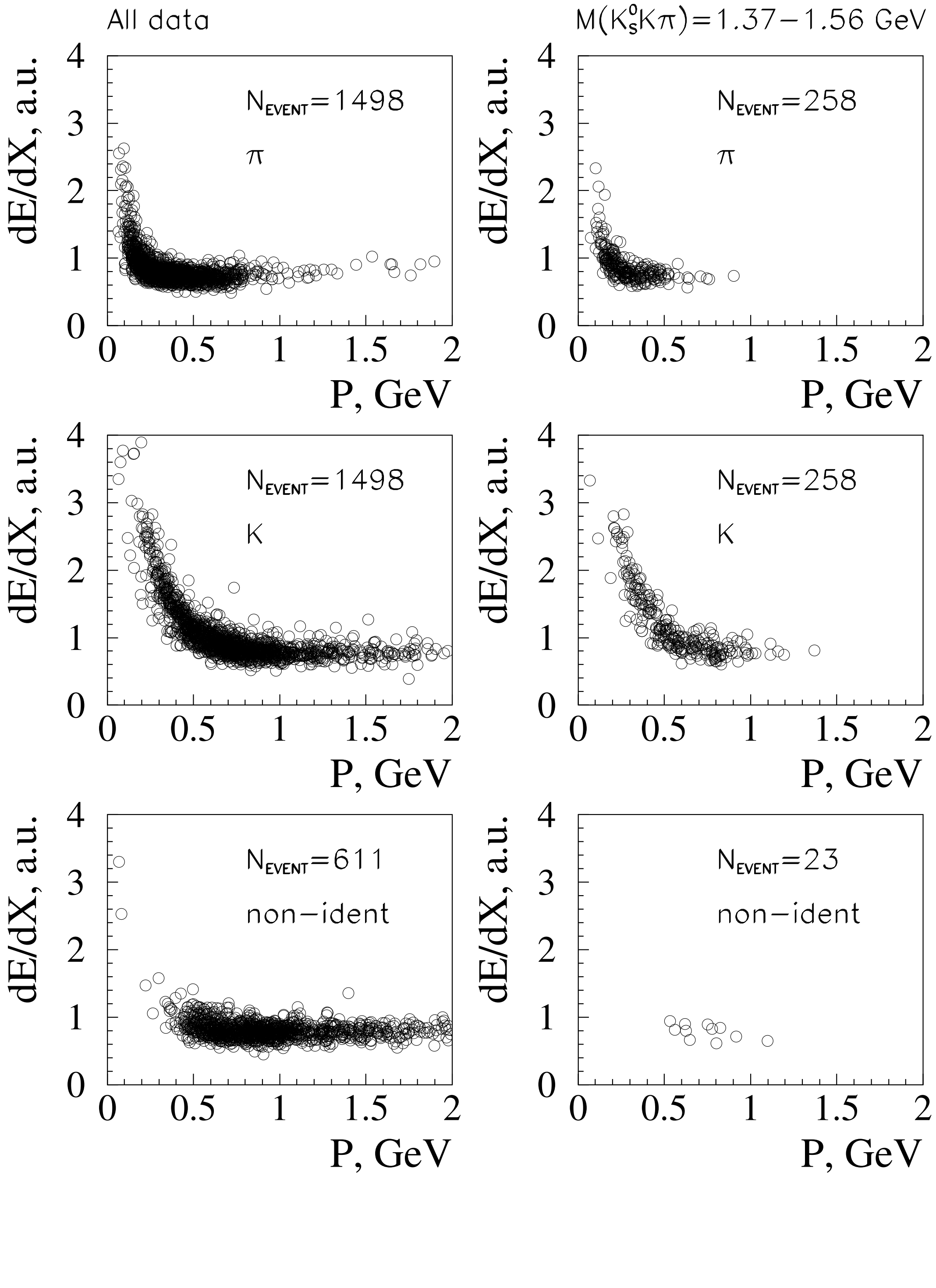
❐ There are experimental indications for the presence of two pseudoscalars in $\eta(1440)$ structure. $K^0_S K^{\pm}\pi^{\mp}$ state splits into $a_0(980)\pi$ with $M = 1418.7 \pm 1.2$ and $K\bar{K}^*(892)$ with $M = 1473 \pm 4$

$K_S^0\, K^{\pm}\pi^{\mp}$ **selection**

- Events: 4 good tracks ; No photons
- Primary vertex: $K^{\pm}\pi^{\mp}$
- Secondary vertex ($\pi^+\pi^-$): $2\,mm \leq R_{XY} \leq 200\,mm$
- Lifetime cut for K_S^0: $1 - exp(-d/\beta\gamma c\tau) \leq 0.99$
- Mass $K_S^0 =$ 0.458–0.528 GeV ; No 2^{nd} K_S^0
- dE/dX identification: $K\pi$ separation



$K_S^0 K^{\pm}\pi^{\mp}$ selection: dE/dX identification



$K^0_S K^\pm \pi^\mp$ mass spectrum

❒ L3 data obtained in 1996–1998 at $160 < \sqrt{s} < 189$ GeV for total integrated luminosity of 250 pb^{-1}

❒ Two peaks are seen: at (1.37–1.56) GeV and $\eta_c(2980)$

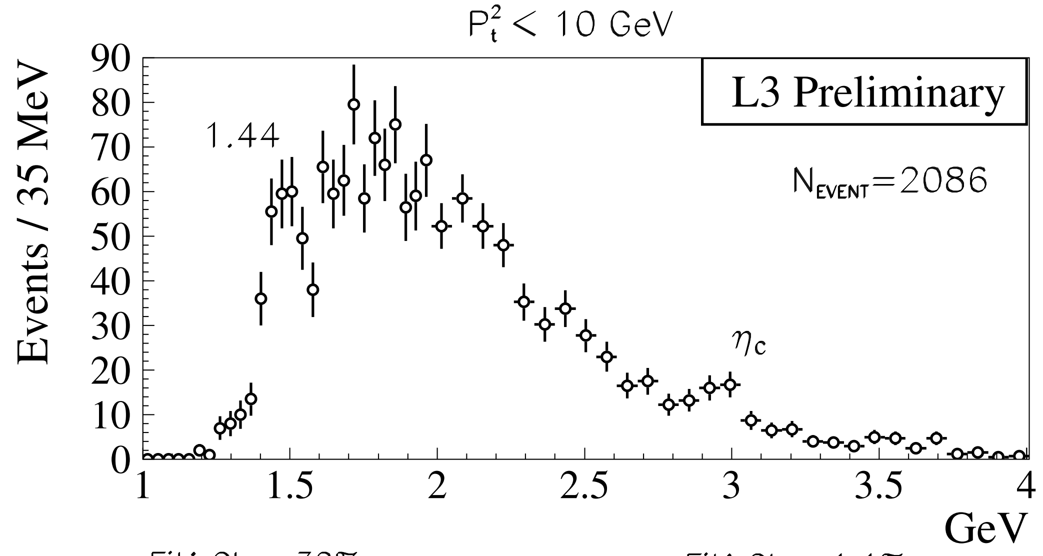
First peak was fitted with $\frac{P1}{1+exp((P2-x)/\sqrt{P3})}$ + Gaussian

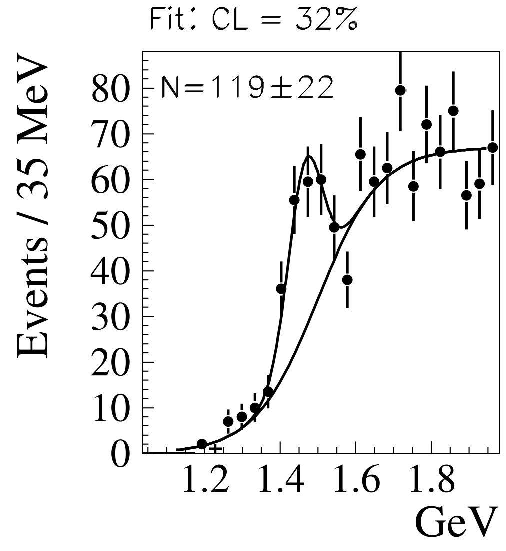
Gaussian parameters for R(1440):

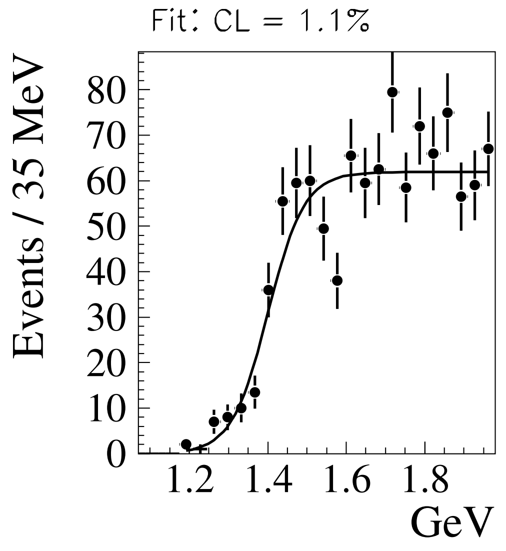
M $= 1.465 \pm 0.031$ GeV

$\sigma = 0.045 \pm 0.005$ GeV (MC mass resolution 24 MeV)

Then they were fixed to these values.







$\Gamma_{\gamma\gamma}$ of $K_S^0 K^{\pm}\pi^{\mp}$ resonances

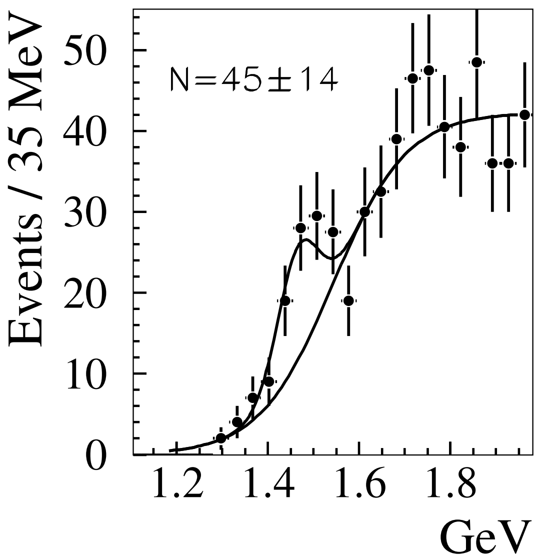
- $\Gamma_{\gamma\gamma}$ is derived: $\sigma(e^+e^- \to e^+e^- R) = \mathcal{K}\,\Gamma_{\gamma\gamma}$

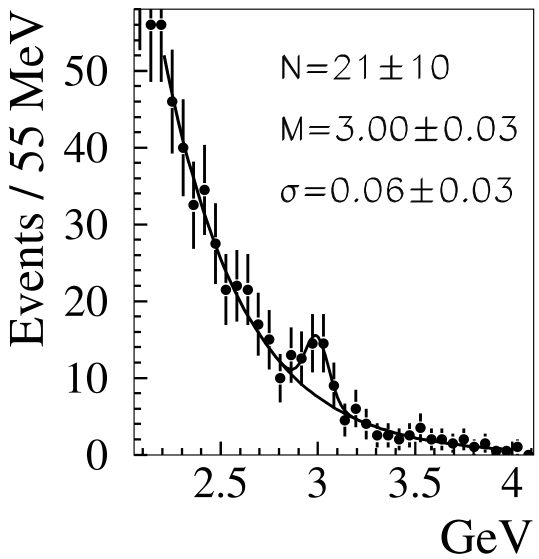
  $\Gamma_{\gamma\gamma} \cdot BR = \frac{N}{\mathcal{K}\,\epsilon\,\mathcal{L}}$

  where: Efficiency ϵ and $\mathcal{K}$ – from EGPC MC
  $\mathcal{L}$–integrated luminosity

We used simulations $\gamma\gamma \to \eta(1440)$ with ρ-mass pole and $\gamma\gamma \to \eta_c$ with J/ψ-mass pole form factor

$P_t^2 < 0.1$ GeV





$\eta(1440)$	$\eta_c(2980)$
ϵ =2.01%	ϵ =6.23%
$\Gamma_{\gamma\gamma} \cdot BR$=43±14$_{stat}$ eV	$\Gamma_{\gamma\gamma} \cdot BR$=63±29$_{stat}$ eV
$\Gamma_{\gamma\gamma} \cdot BR < 274$ eV — CELLO **	$BR(K_S^0(\to \pi^+\pi^-)\,K^{\pm}\pi^{\mp})$=1.26%
	$\Gamma_{\gamma\gamma}$=5.3±2.5$_{stat}$ keV
	$\Gamma_{\gamma\gamma}$=6.9±1.7$_{stat}$ keV — L3 last*
	$\Gamma_{\gamma\gamma}$=7.5±1.6 keV — PDG

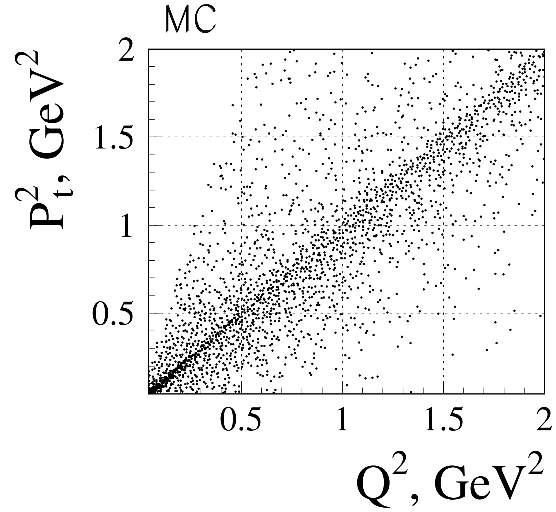
* See report of A.Buijs (Photon99)
** Z.Phys.C 42(1989)367

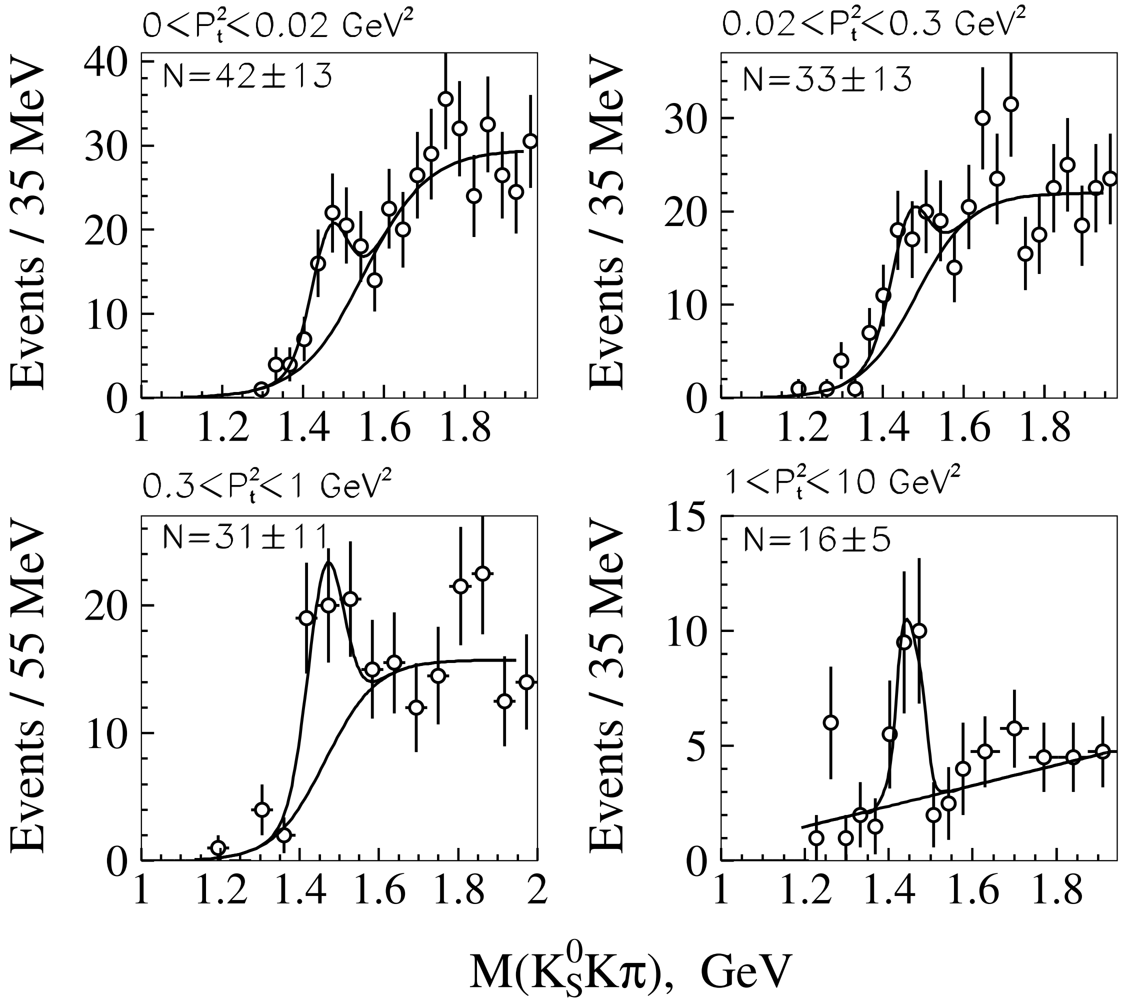
$K_S^0 K^\pm \pi^\mp$: R(1440) yield vs Q^2

We used $P_t^2(K_S^0 K^\pm \pi^\mp)$ instead of Q^2:

More than 90% of values differ less than for 0.02 GeV^2

Most probable difference (Q^2 - P_t^2) is of 0.001 GeV^2





$K^0_S K^{\pm}\pi^{\mp}$: R(1440) yield vs Q^2

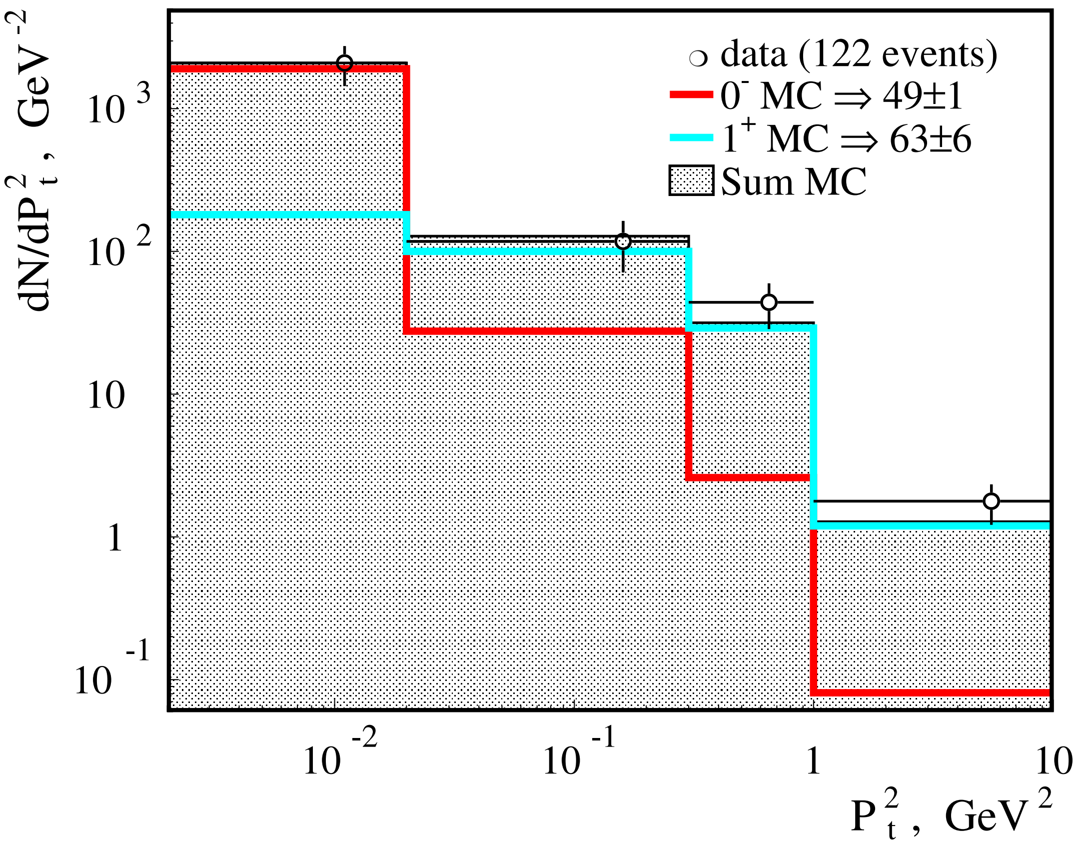
$$\sigma(\gamma\gamma \to R) = 8\pi(2J+1)\,F^2(Q^2)\,\frac{\Gamma_{\gamma\gamma}\Gamma_R}{(W^2-M^2)^2+M^2\,\Gamma_R^2}$$

Comparison is given to two Monte-Carlo samples:

1. with $F^2_{[0-]}(Q^2) = \frac{1}{(1+Q^2/\Lambda^2)^2}$ where $\Lambda = m_\rho$
2. with $F^2_{[1+]}(Q^2) = \frac{2}{(1+Q^2/\Lambda^2)^4}\frac{Q^2}{\Lambda^2}(1+\frac{Q^2}{2\Lambda^2})$ *

Compatibilities of simulations for experimental data separately are: for 0^- CL<1%, and for 1^+ CL<1%

Simulated data are normalised by fitting their sum to experimental data, CL = 50%. (Errors are only from the fit)



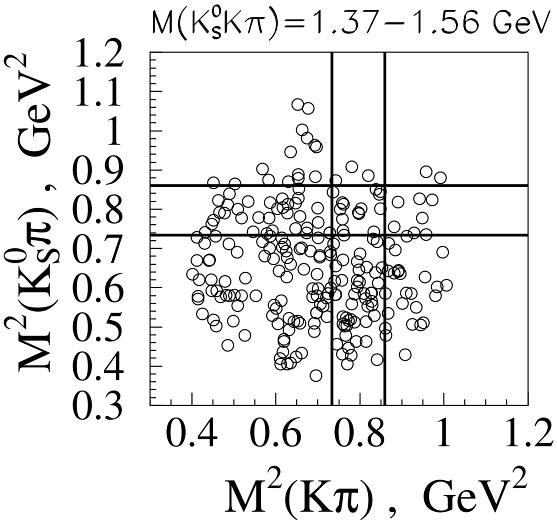
As we have high yield for $Q^2 \approx 0$, one should conclude, that the state under investigation has significant 0^- component: η(1440) but also 1^+ component f_1 is possible for higher Q^2.

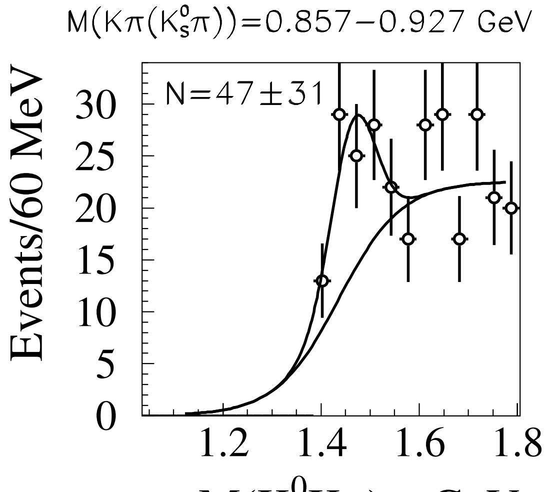
* G.A.Schuler et al Nucl.Phys.B 523(1998)423

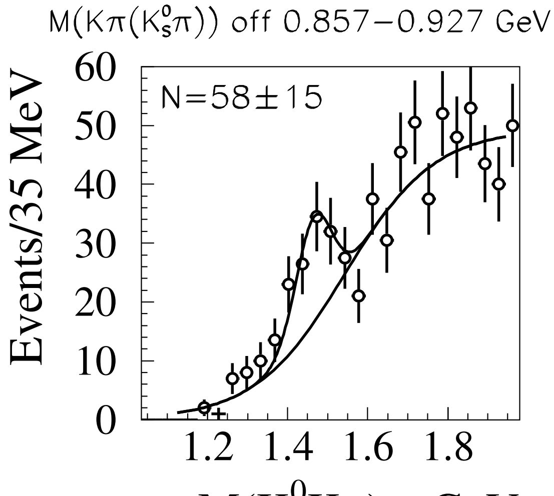
R(1440) Decay Modes: $K\bar{K}^{*}(892)$+c.c.

❒ Decay modes are studied in cases when kaon and pion in primary vertex are identified

Dalitz plot for testing of $K^*(892)$ in $K\pi$ or $K_s^0\pi$ masses doesn't give an apparent signal. Nevertheless, 446 events from total statistics of 1498 were selected when mass of $K\pi$ or $K_s^0\pi$ was close to M($K^*(892)$).



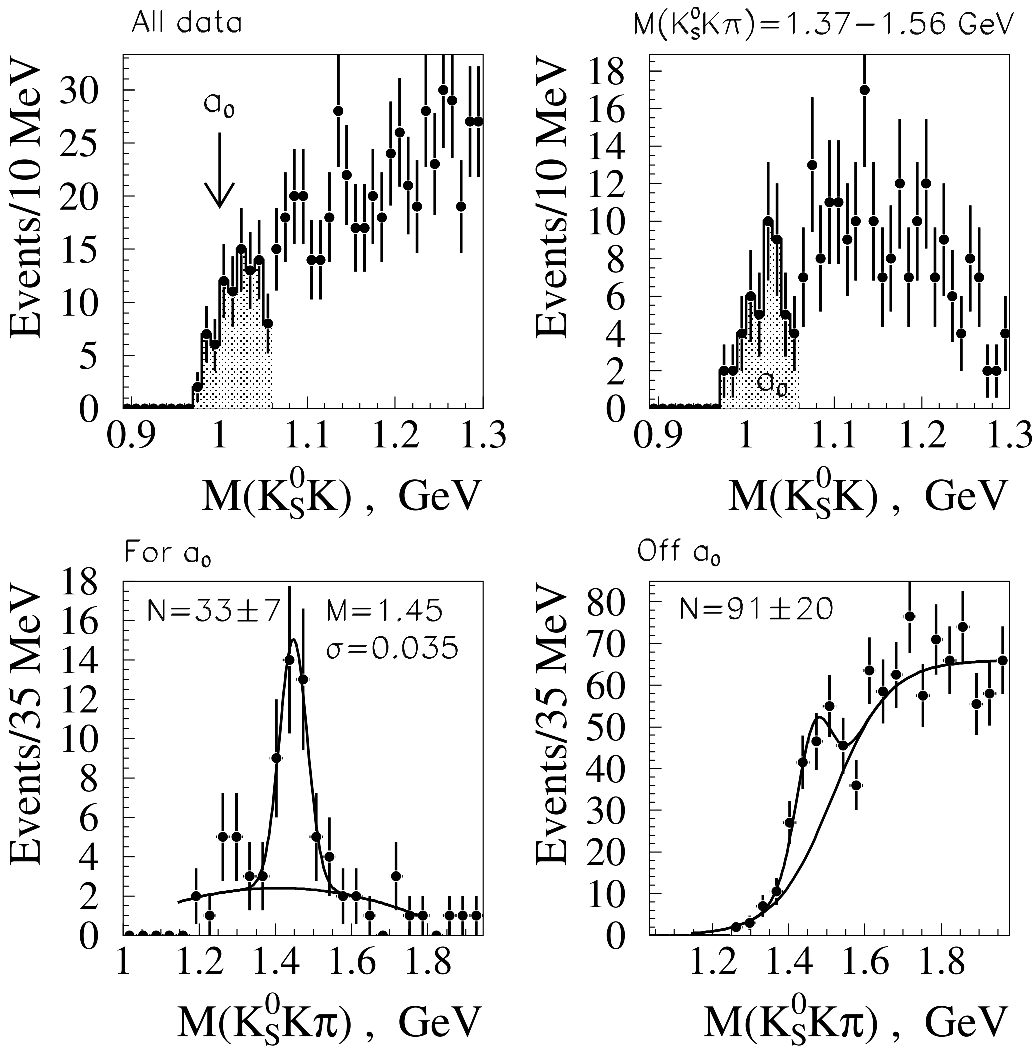




Although peak R(1440) for $K^*(892)$ masses is seen, it is difficult to declare a presence of this decay mode.

R(1440) Decay Modes: $a_0(980)\pi$

KK^0_S mass distribution shows a possible presence of $a_0(980)$. 70 events with M(KK^0_S)<1.06 GeV were selected from the full data sample of 1498 events.



The R(1440) peak for $a_0(980)$ case was fitted with free parameters. The Mean of Gaussian 1.45±0.01 GeV is smaller than that for total spectrum (1.465 GeV) and closer to PDG average for $\eta(1440)$ 1.419 GeV.

Branching Ratio for $a_0(980)\pi$ decay mode in R(1440) to $K^0_S K^\pm \pi^\mp$ decay was evaluated to be 0.28±0.08$_{stat}$

$\eta(1440)$: test of gluonium hypothesis

To quantify the flavour content of a resonance, one uses a parameter stickiness:

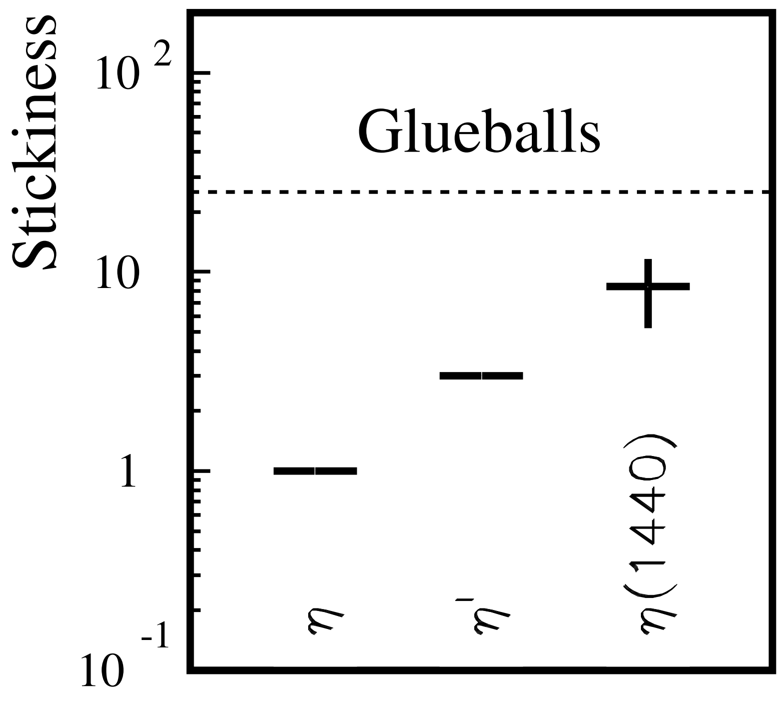
$$S_X = N_l \left(\frac{m_X}{K_{J/\psi \to \gamma X}} \right)^{2l+1} \frac{\Gamma(J/\psi \to \gamma \mathsf{X})}{\Gamma(\mathsf{X} \to \gamma\gamma)} \sim \frac{|\langle \mathsf{X}|\mathrm{gg}\rangle|^2}{|\langle \mathsf{X}|\gamma\gamma\rangle|^2}$$

$K_{J/\psi \to \gamma X}$ is the energy of photon in a $J/\psi \to \gamma$X decay,
N_l is a normalisation factor chosen so that S_X is equal to one for η

The value obtained
$\Gamma_{\gamma\gamma} \cdot BR(\eta(1440) \to K^0_S K^\pm \pi^\mp \to \pi^+\pi^- K^\pm \pi^\mp)$=43 eV leads to:

$S_X(\eta(1440)) \approx 8.4 \pm 3.2$

It means that $\eta(1440)$ has usual flavour content.



R(1440): conclusions

- Resonance(1440) was for the first time observed in non-tagged $\gamma\gamma$ collisions
- In the hypothesis of $\eta(1440)$ $I^G(J^{PC}) = 0^+(0^{-+})$ $\Gamma_{\gamma\gamma} \cdot BR(\mathrm{K^0_S}(\rightarrow \pi^+\pi^-)\,\mathrm{K}^\pm\pi^\mp) =$ 43$\pm$14$_{stat}$ eV
- Presence of both spin zero and spin one components is required by the Q^2 distribution of the data
- $a_0(980)\pi$ decay mode is seen clearly. Branching Ratio for $a_0(980)\pi$ decay mode to total $K^0_S\,K^\pm\pi^\mp$ decay rate was evaluated to be 0.28$\pm$0.08$_{stat}$
- The hypothesis that the $\eta(1440)$ state could be gluonium has not been confirmed