The $K^0_s K^0_s$ and the $K^0_s K^\pm \pi^\mp$ Final States in Two-Photon Collisions at LEP and Glueball Searches

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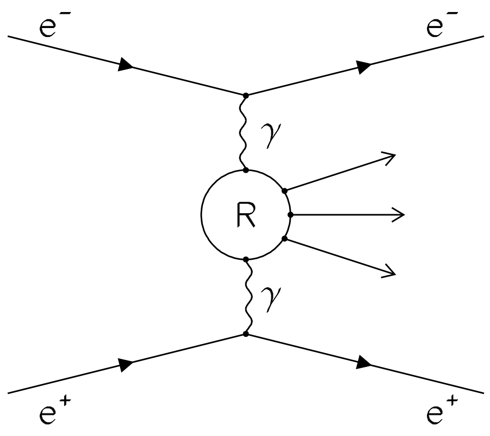
$\gamma\gamma$ *reactions*

$e^+e^- \to e^+e^-\gamma\gamma \to e^+e^-R$

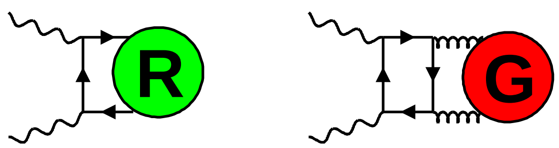


$$\boldsymbol{\sigma}(e^+e^- \to e^+e^-\boldsymbol{R}) = \boldsymbol{\mathcal{K}} \cdot \boldsymbol{\Gamma_{\gamma\gamma}}$$

Quantum numbers restricted:

- R neutral unflavoured meson with C=+1
- $Q^2 \approx 0 \longrightarrow$ quasi-real photons $\longrightarrow$ J$\neq$1
- $Q^2 > 0 \longrightarrow$ J=1 is possible

Gluonium:



$\Rightarrow \Gamma_{\gamma\gamma}$(G) is very small !

L3 Detector at LEP

$$e^+e^- \rightarrow e^+e^-\gamma\gamma \rightarrow e^+e^- \; K^0_s K^0_s$$
$$e^+e^- \; K^0_s K^\pm \pi^\mp$$

Outgoing e^+e^- are undetected ("Untagged events")

- $K^0_s K^0_s$ final state :

  LEP I: $\sqrt{S}$=91 GeV, L=143 pb^{-1}

  LEP II: $\sqrt{S}$=183 GeV, L=52 pb^{-1};
  $\sqrt{S}$=189 GeV, L=172 pb^{-1}

  $Q^2 \approx |\vec{p}_T(\pi^+\pi^-\pi^+\pi^-)|^2 < 0.1$ GeV^2

  $J^{PC} = 0^{++}$ and 2^{++}

  499 events are selected

- $K^0_s K^\pm \pi^\mp$ final state :

  LEP II: $\sqrt{S}$=160 - 189 GeV, L=250 pb^{-1}

  K distinguished from π by dE/dX

  $Q^2 \approx |\vec{p}_T(\pi^+\pi^-K^\pm\pi^\mp)|^2 < 10$ GeV^2

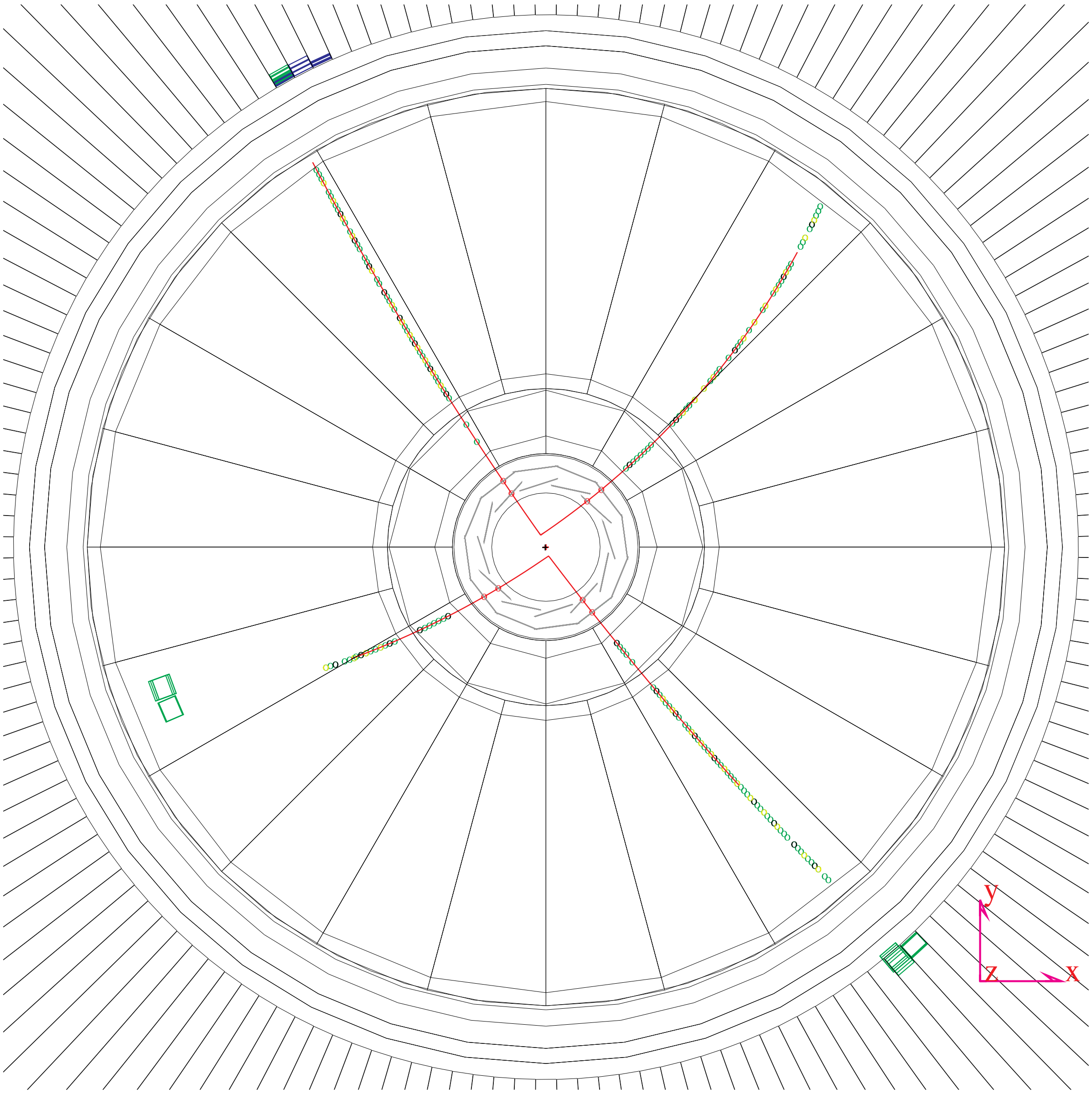
  $J^{PC} = 0^{-+}$ and 1^{++}

  2086 events are selected

A $\gamma\gamma \rightarrow K_s^0 K_s^0$ event

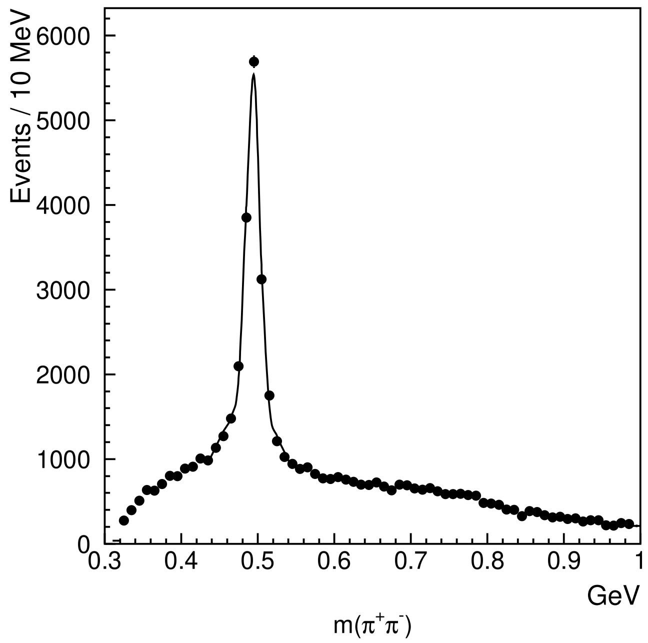
L3 Detector at LEP

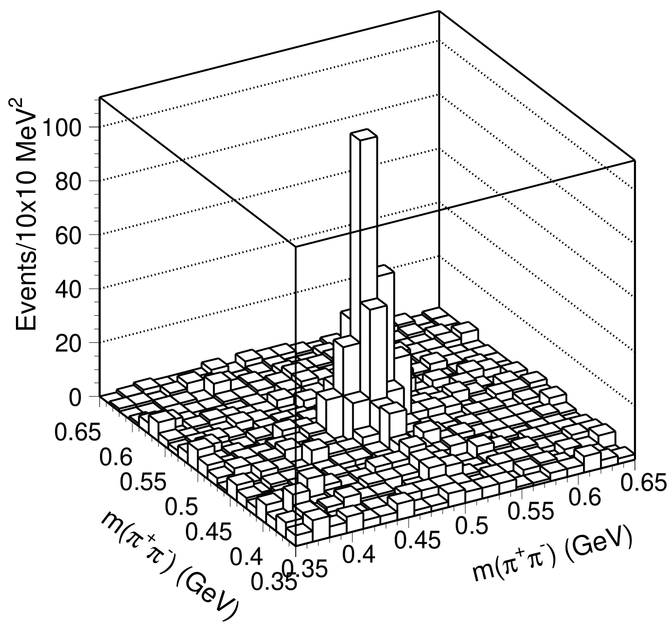
Run # 689002 Event # 287 Total Energy : .78 GeV



K_s^0 *mass*

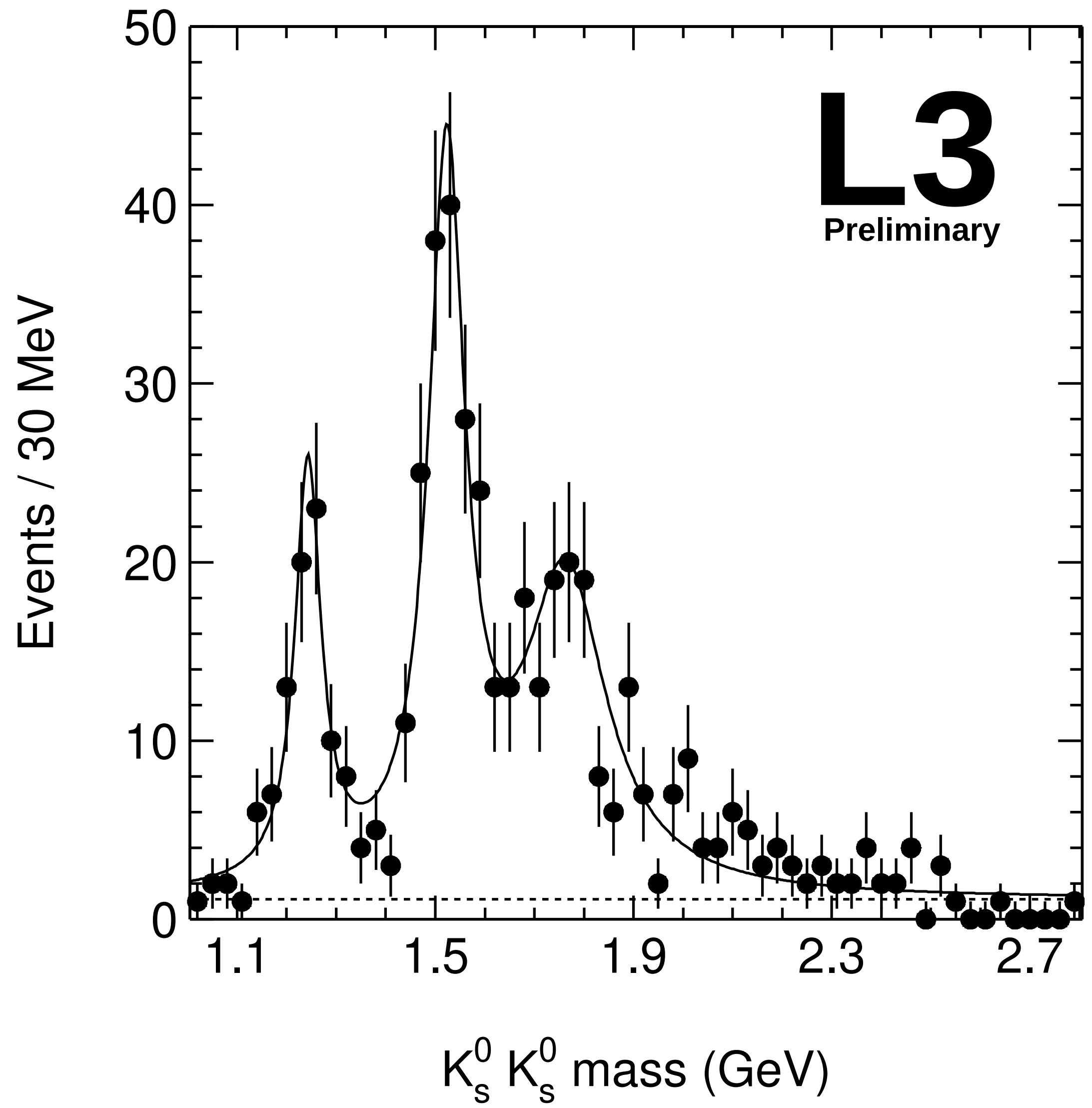
$$\gamma\gamma \to K_s^0 K_s^0$$





$M_{\pi^+\pi^-}$ inside a circle around K_s^0 mass (R= 40 MeV)

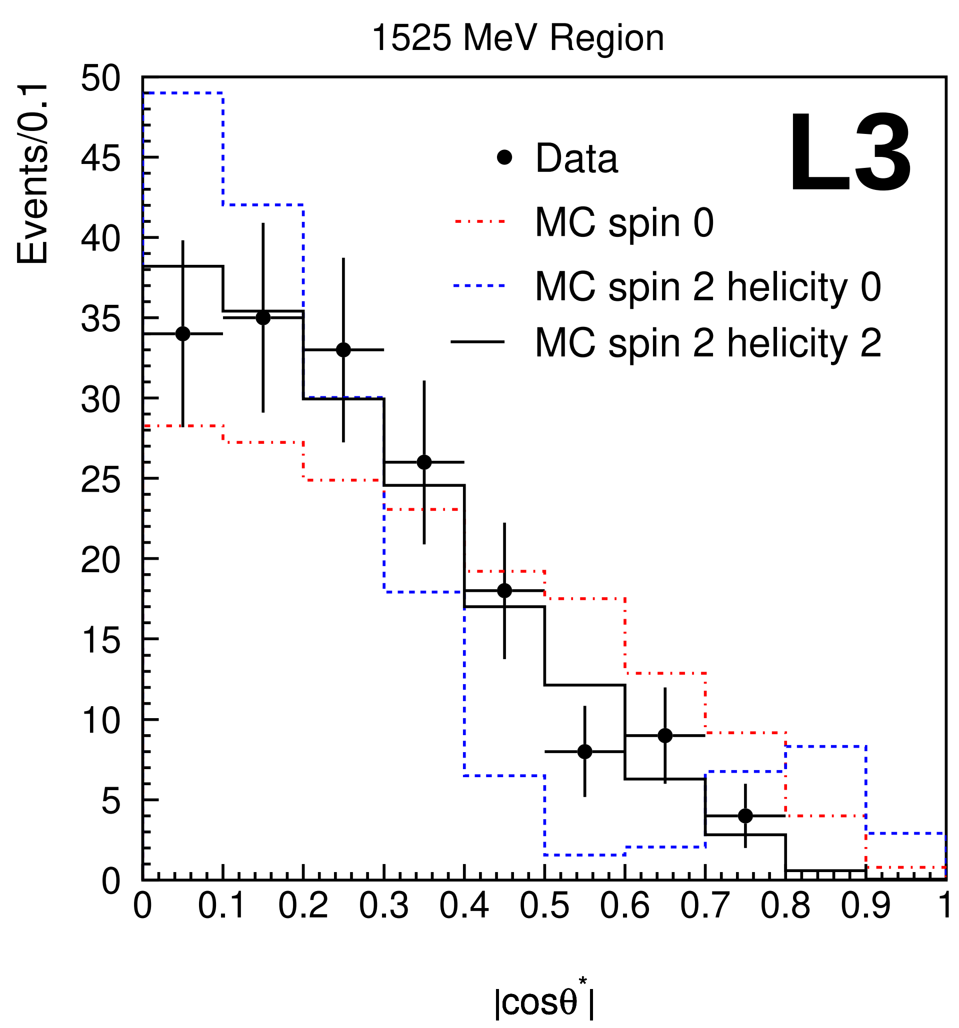
$K^0_s K^0_s$ *mass spectrum*



	f_2-a_2	$f_2'(1525)$	1750 MeV
Mass (MeV)	—	1523 ±8	1765±22
Width (MeV)	—	89 ±37	200±50
Events	75±15	184±27	171±26

- ❏ $f_2 - a_2$ destructive interference
- ❏ Clear $f_2'(1525)$ signal
- ❏ Clear enhancement (7 σ) in the 1750 MeV region
- ❏ No signal in the $\xi(2230)$ region

$K_s^0 K_s^0$: the $f_2'(1525)$



	$J=0$	$J=2,\ \lambda=2$	$J=2,\ \lambda=0$
χ^2 for 7 d.o.f.	22.5	4.2	28.5

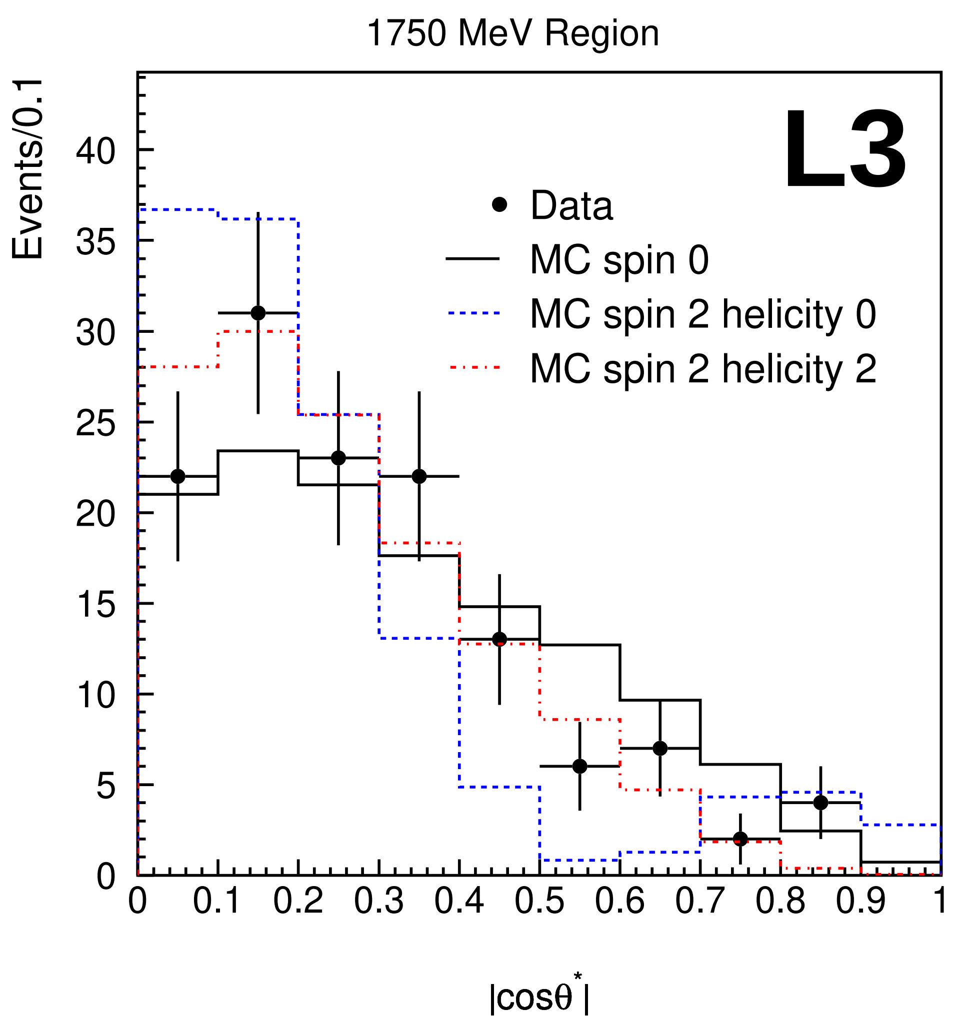
Helicity 2 dominates !

For helicity 2 the detection efficiency is 7.6% at LEP I and 6.4% at LEP II.

$$\Gamma\gamma\gamma(f_2') \times \mathrm{BR}(K\bar{K}) = (0.093 \pm 0.018 \pm 0.022)\,\mathrm{keV}$$

PDG value: $(0.086 \pm 0.012)\,\mathrm{keV}$

$K_s^0 K_s^0$: *the 1750 MeV region*



	J=0	J=2, λ=2	J=2, λ=0
χ^2 for 8 d.o.f.	17.9	7.2	26.3

$K^0_s K^0_s$: *the* $\xi(2230)$ *region*

Our upper limit:

$\Gamma_{\gamma\gamma}(\xi) \times \mathrm{BR}(\xi \to K^0_s K^0_s) < 1.5$ eV at 95% C.L.

Stickiness:

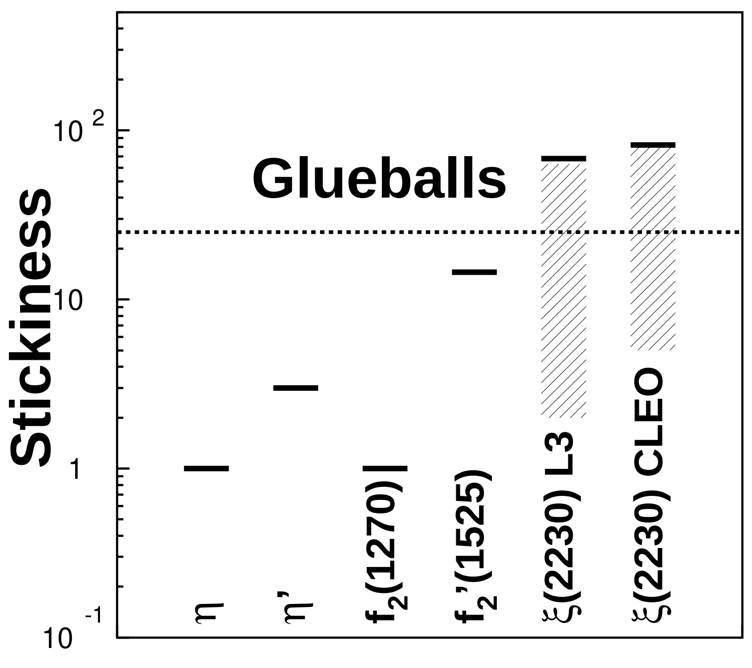
$$S_R = N_l \left(\frac{m_R}{k_{J/\psi \to \gamma R}} \right)^{2l+1} \frac{\Gamma(J/\psi \to \gamma R)}{\Gamma(R \to \gamma\gamma)} \sim \frac{|<R|gg>|^2}{|<R|\gamma\gamma>|^2}$$

where:

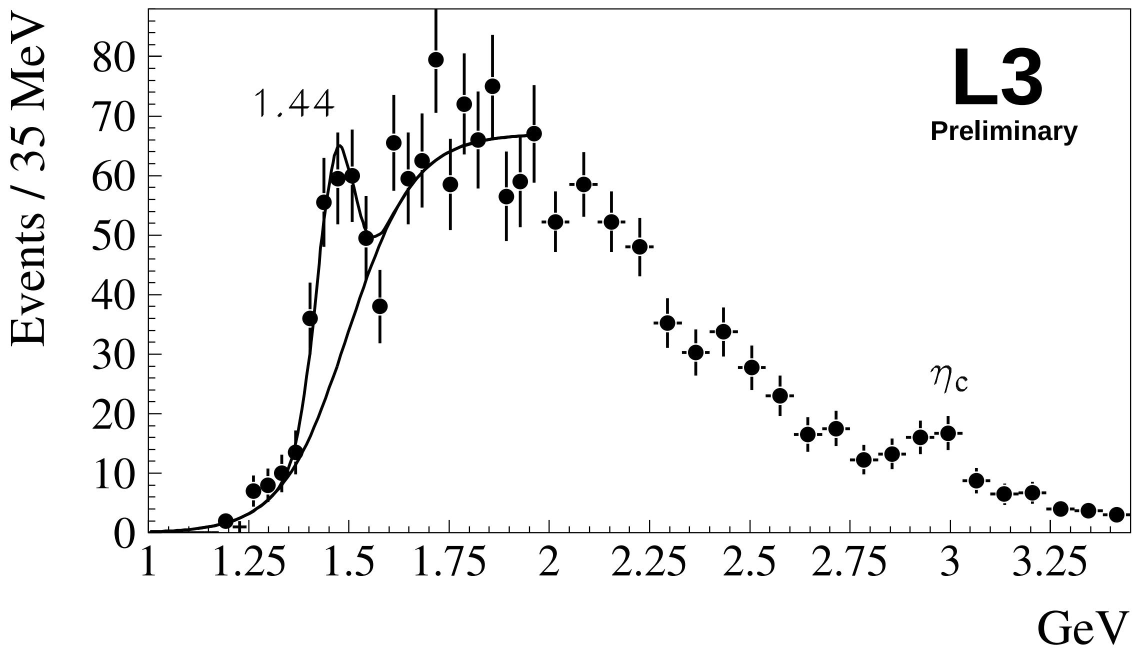
m_R	mass of the state
$k_{J/\psi\to\gamma X}$	photon energy in J/ψ decay
N_l	normalization factor such that $S_{f_2(1270)}=1$

Combining the upper limit with results from Mark III and BES we obtain

$S_\xi > 68$ at 95% C.L.



$K^0_s K^{\pm}\pi^{\mp}$ *mass spectrum*



Peak at (1.37–1.56) GeV is first time seen in untagged events

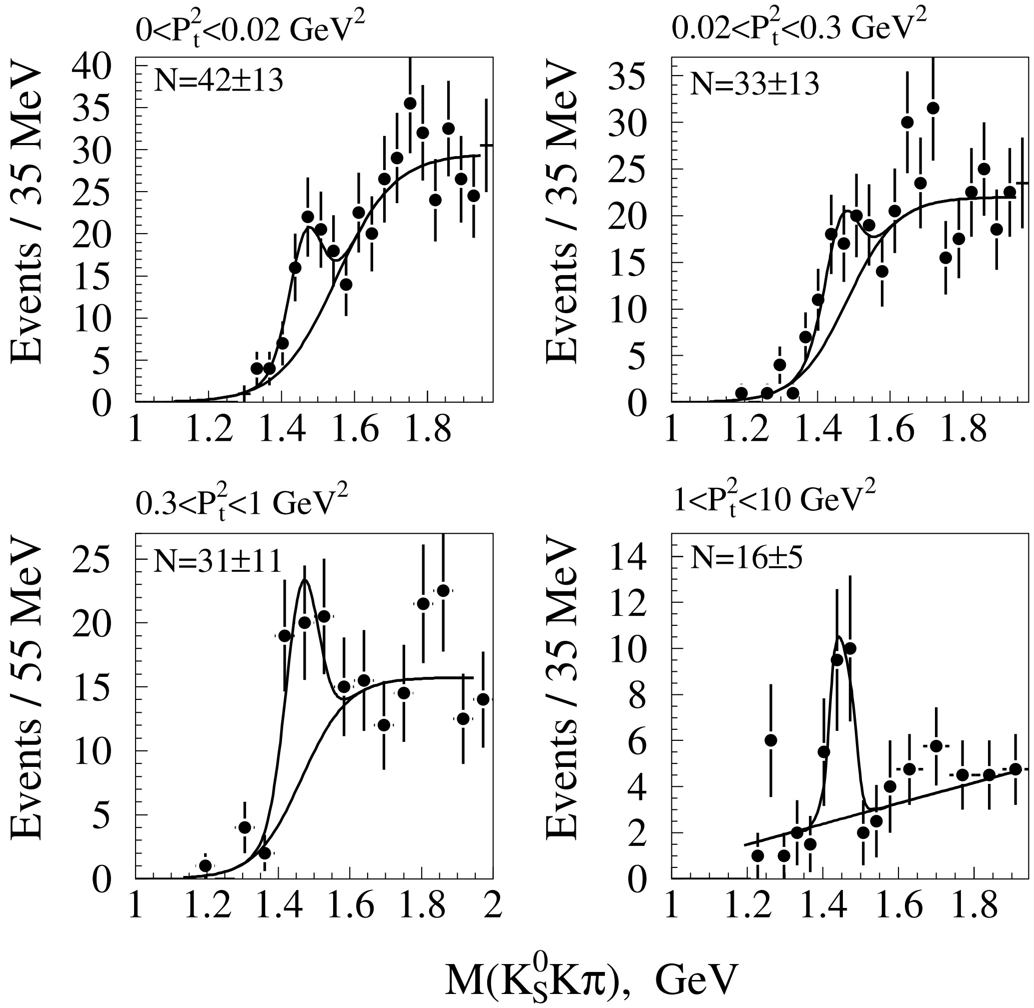
The peak was fitted with $\frac{P1}{1+exp(P2-P3\cdot x)}$ + Gaussian

Gaussian parameters for R(1440):

M $= 1.465 \pm 0.031$ GeV

$\sigma = 0.045 \pm 0.005$ GeV

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

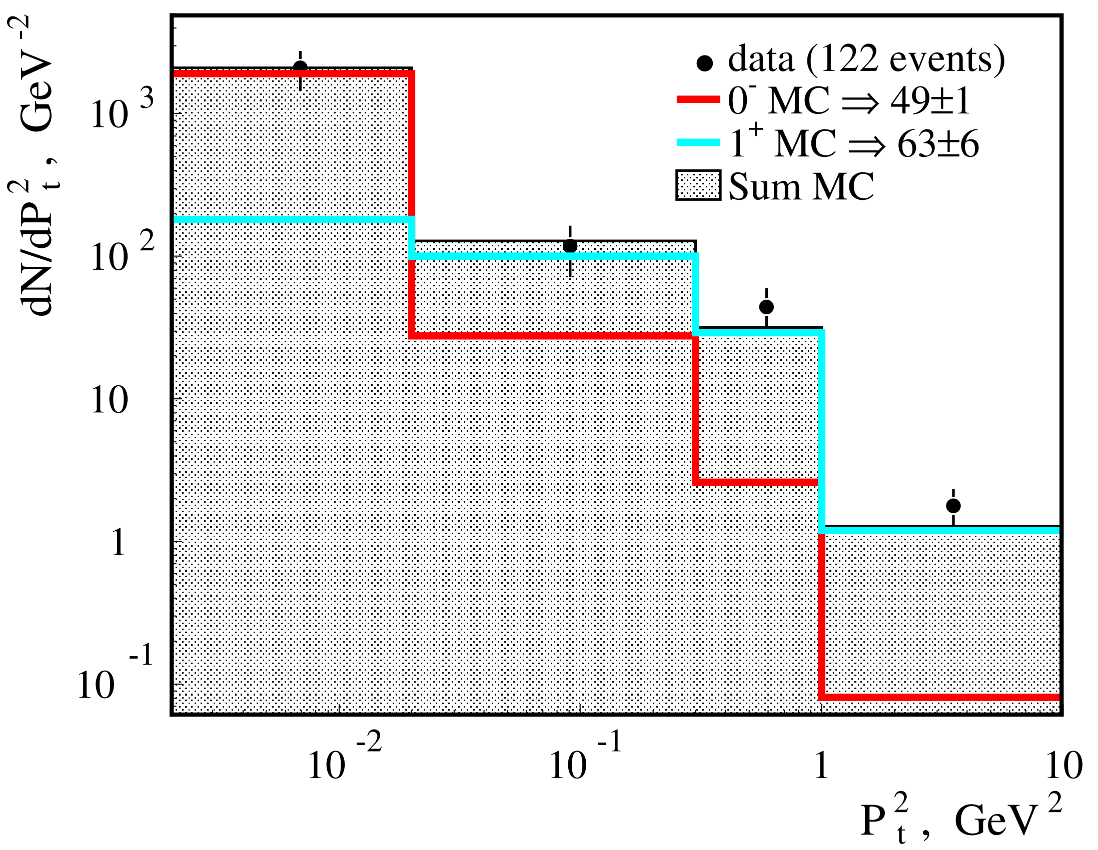


$Q^2 \approx P_t^2$:

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

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

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



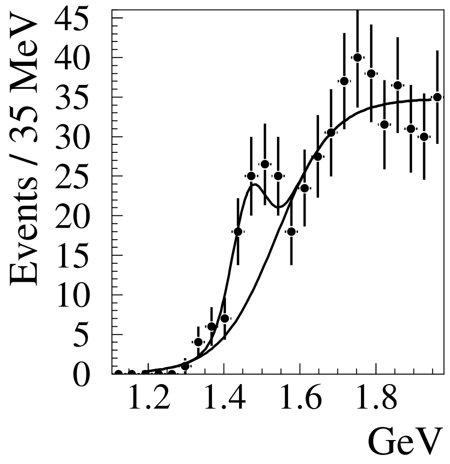
$$\sigma(\gamma\gamma \to R) = 8\pi(2J+1)\, F^2(Q^2)\, \frac{\Gamma_{\gamma\gamma}\Gamma_R}{(W^2-M^2)^2+M^2\,\Gamma_R^2}$$

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 $F^2_{[1+]}(Q^2) = \frac{2}{(1+Q^2/\Lambda^2)^4}\frac{Q^2}{\Lambda^2}(1+\frac{Q^2}{2\Lambda^2})$

$\mathbf{K^0_s K^{\pm}}\pi^{\mp}$: $\Gamma_{\gamma\gamma}$ *and stickiness*

$$P_t^2 < 0.05 GeV^2$$



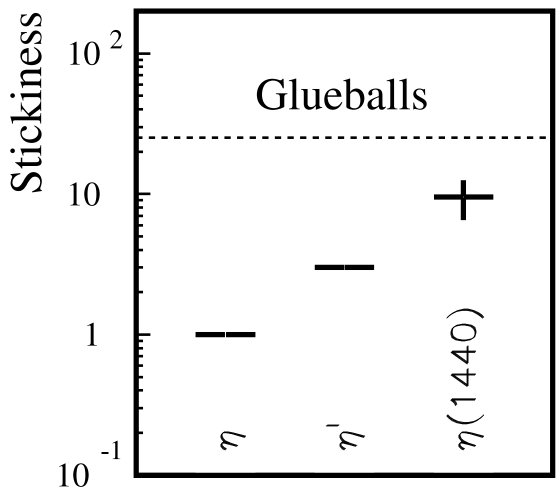
N $=$ 44 $\pm$ 14, ϵ =1.87 %

$\Gamma_{\gamma\gamma} \cdot BR(K\bar{K}\pi)$=166$\pm$52$_{stat}$ eV

$\Gamma_{\gamma\gamma} \cdot BR(K\bar{K}\pi) <$ 1200 eV - CELLO

Stickiness $S_{\eta(1440)}$ $=$ 9.5$\pm$3.0

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



Conclusions

$K^0_s K^0_s$ final state:

- $f'_2(1525)$, $J^{PC}(\lambda)=2^{++}(2)$
- $f_2 - a_2$ destructive interference
- Enhancement of 7σ in the 1750 MeV region: both 0^{++} and 2^{++} can be present
- No signal for the $\xi(2230)$:
  $\Gamma_{\gamma\gamma}(\xi) \times \mathrm{BR}(\xi \to K^0_s K^0_s) < 1.5$ eV
  $S_\xi > 68$ at 95% C.L.

$K^0_s K^\pm \pi^\mp$ final state:

- Resonance(1440) is for the first time observed in non-tagged $\gamma\gamma$ collisions
- Presence of both 0^{-+} and 1^{++} components is required by the Q^2 distribution of the data
- For the $\eta(1440) I^G(J^{PC}) = 0^+(0^{-+})$
  $\Gamma_{\gamma\gamma} \cdot BR(\mathrm{K^0_S}(\to \pi^+\pi^-)\,\mathrm{K}^\pm\pi^\mp) = 166 \pm 52_{stat}$ eV
- $S_{\eta(1440)} = 9.5 \pm 3.0$
  Gluonium hypothesis is not confirmed