Analysis of $K^0_s K^0_s$ and $\pi^+\pi^-\pi^0$ final states in two photon collisions at LEP

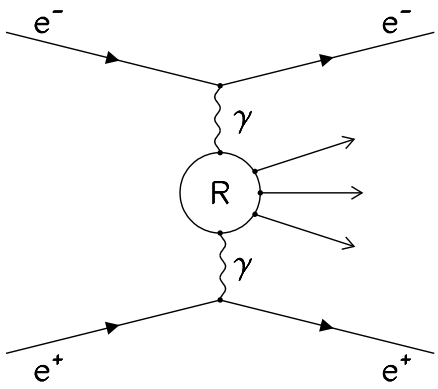
Igor Vorobiev
Carnegie Mellon University

representing the

L3 Collaboration

EPS, High Energy Physics 2003
Aachen, Germany
17-23 July 2003

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



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

Quantum numbers restricted:

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

$$\gamma\gamma \rightarrow K^0_s K^0_s$$

- Allowed states $J^{PC} = 0^{++}, 2^{++}, 4^{++}, ...(2n)^{++}$

$$\gamma\gamma \rightarrow \pi^+\pi^-\pi^0$$

- 0^+ excluded by parity conservation
- Only isovector $q\bar{q}$ states can be produced $I^G = 1^-$
- Allowed states $J^{PC} = 0^{-+}, 2^{++}, 2^{-+}, ...$

L3 Detector at LEP

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

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: $\sqrt{S}$=183-209 GeV, L=663 pb^{-1}

$$d_0 = d\frac{M_{K_S}}{P_{K_S}} > 1.5 \text{ mm}$$

$$P_t = |\sum \vec{p}_t| < 0.3 \text{ GeV}$$

870 events are selected

- $\pi^+\pi^-\pi^0$ final state :

LEP II: $\sqrt{S}$=189 - 209 GeV, L=609 pb^{-1}

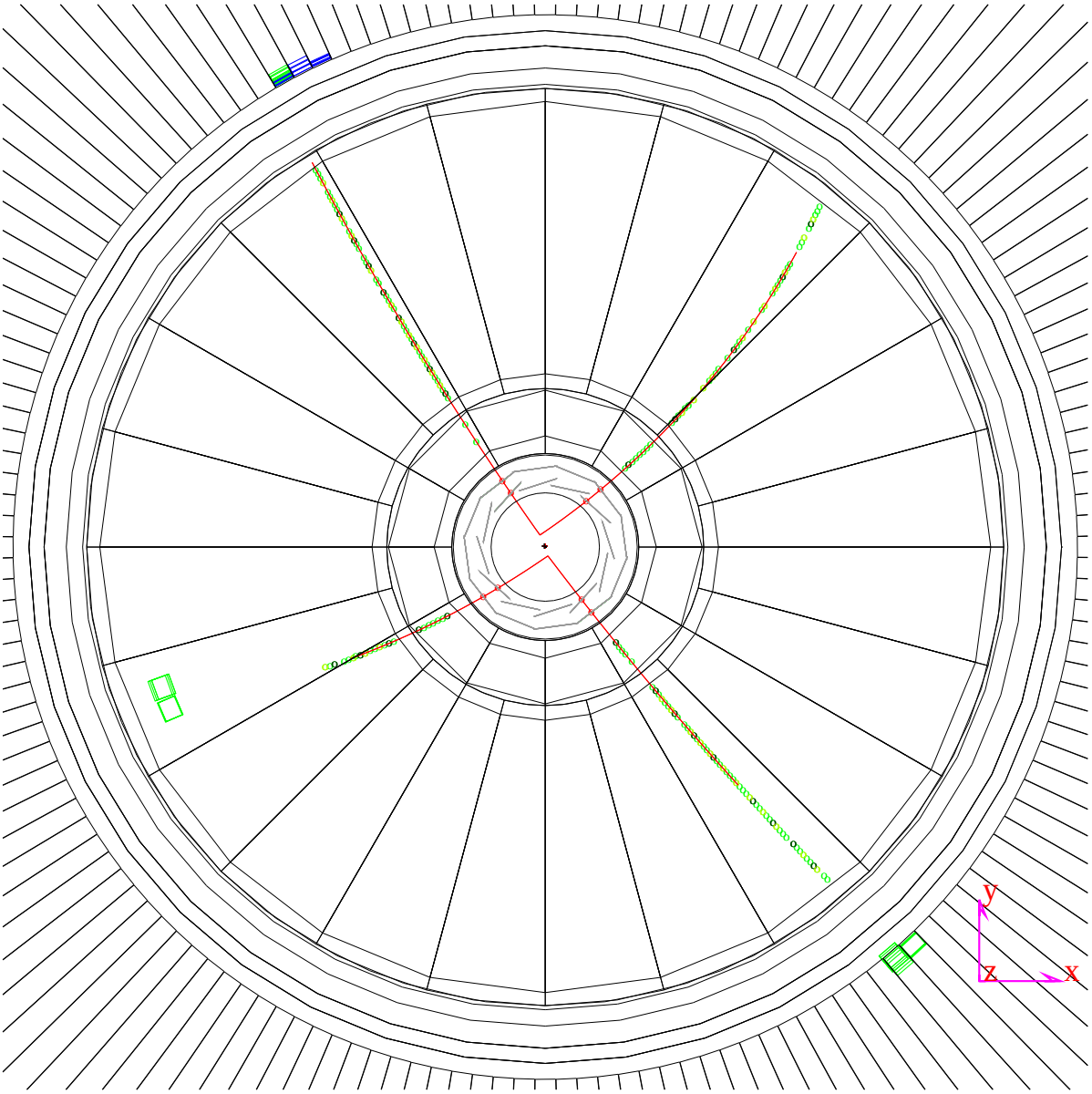
$$0.065 < m_{\gamma\gamma} < 0.220 \text{ GeV}$$

$$P_t = |\sum \vec{p}_t| < 0.1 \text{ GeV}$$

16579 events are selected

L3 Detector at LEP

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



Full energy dependent Partial Wave Analysis

Done by theorists from PNPI, St.Petersburg:
A.Anisovitch
V.Nikonov
A.Sarantsev

$$\gamma\gamma \rightarrow \mathrm{K}^0_s\mathrm{K}^0_s$$

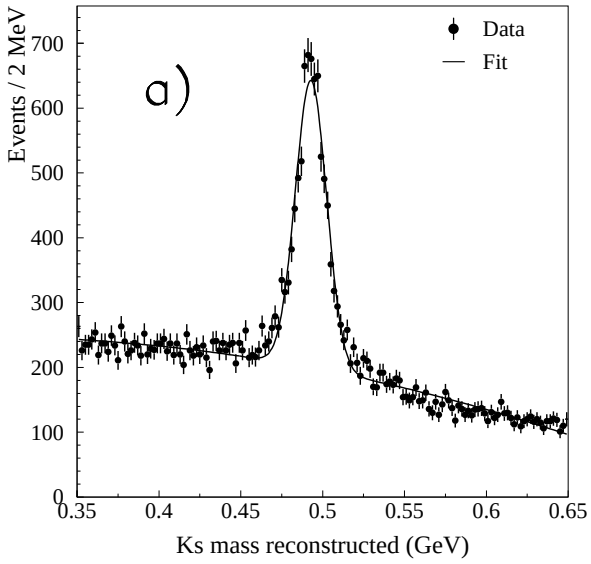
- Range of $\mathrm{K}^0_s\mathrm{K}^0_s$ mass 0.9 - 2.4 GeV.

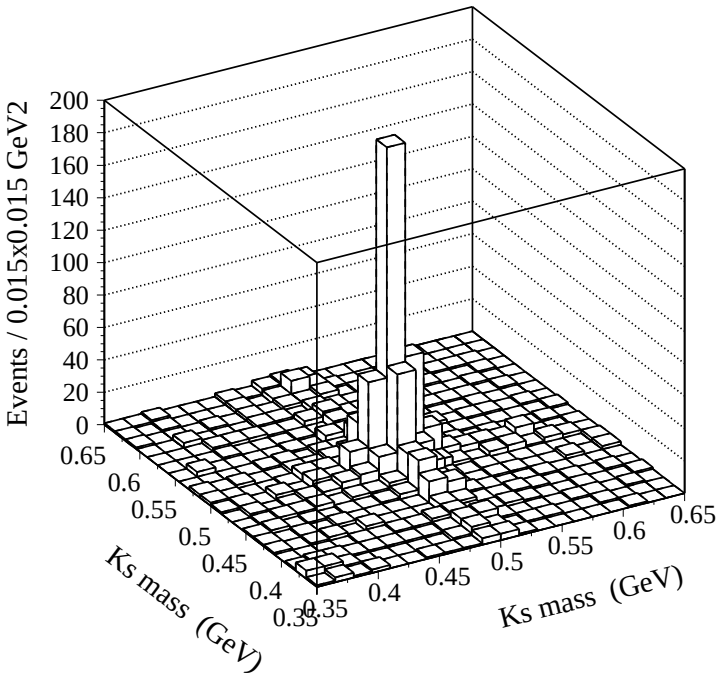
1) Partial wave analysis. Main attention to the state in the 1700 - 1800 MeV region.
2) An analysis of the data from the point of view of SU(3) nonet classification. SU(3) relations are imposed on parameters.

$$\gamma\gamma \rightarrow \pi^+\pi^-\pi^0$$

- Range of $\pi^+\pi^-\pi^0$ mass 0.8 - 2.2 GeV.
- Model : $\gamma\gamma \rightarrow R \rightarrow \pi R'$

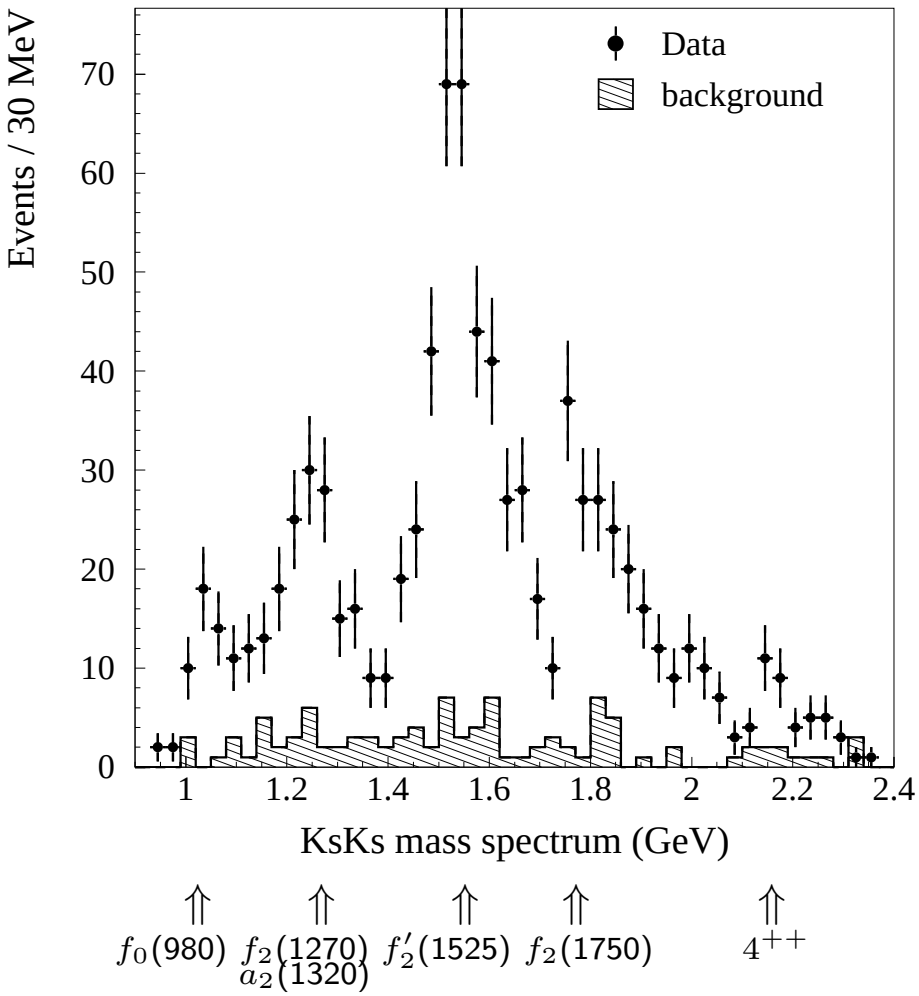
$$\gamma\gamma \to K^0_s K^0_s$$





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

$K^0_s K^0_s$ mass



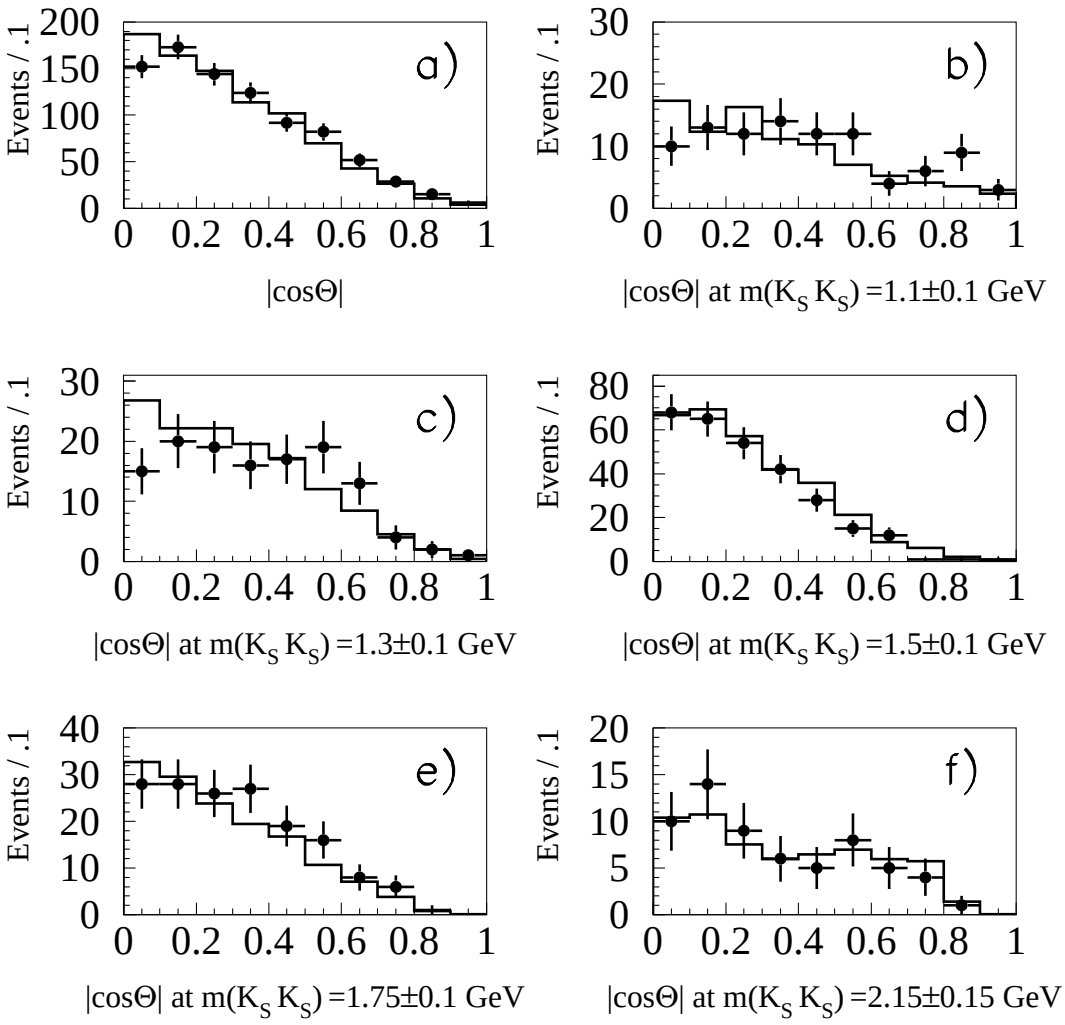
Allowed states $J^{PC} = 0^{++}, 2^{++}, 4^{++}, \ldots$

2^{++} : First nonet - $a_2(1320)$, $f_2(1270)$, $f_2'(1525)$
Second nonet - $a_2(1700)$, $f_2(1560)$, $f_2(1750)$

0^{++} : $f_0(600)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, ...
Scalar amplitudes are fixed (taken from V.V.Anisovich and A.V.Sarantsev, Eur. Phys. J. A16 (2003) 229)

4^{++} : narrow state

$K^0_s K^0_s$ angular distributio ns



$^1S_0\ (\gamma\gamma) \rightarrow\ \ ^1S_0\ (K^0_s K^0_s)\ :\ 1$

$^1D_2\ (\gamma\gamma) \rightarrow\ ^1D_2\ (K^0_s K^0_s)\ :\ \frac{1}{2}(3cos^2\Theta - 1)$

$^5S_2\ (\gamma\gamma) \rightarrow\ \ ^1D_2\ (K^0_s K^0_s)\ :\ (1 - cos^2\Theta)$

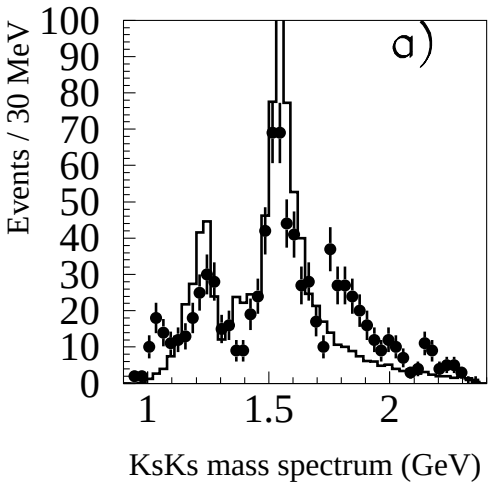
$^1G_4\ (\gamma\gamma) \rightarrow\ ^1G_4\ (K^0_s K^0_s)\ :\ \frac{1}{8}(35cos^4\Theta - 30cos^2\Theta + 3)$

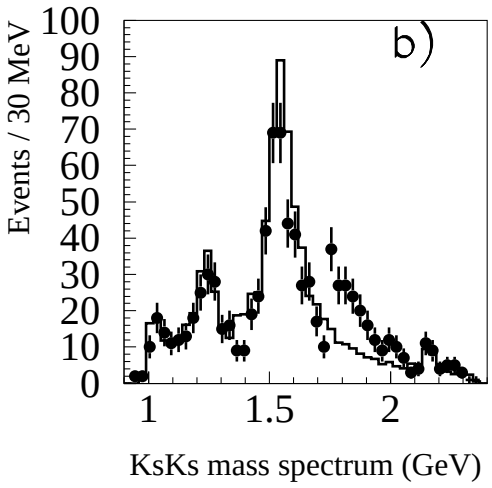
$^5D_4\ (\gamma\gamma) \rightarrow\ ^1G_4\ (K^0_s K^0_s)\ :\ (1 - cos^2\Theta)(7cos^2\Theta - 1)$

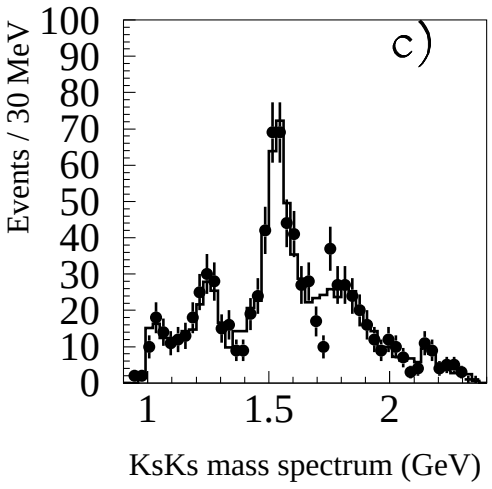
$K^0_s K^0_s$ fit tests

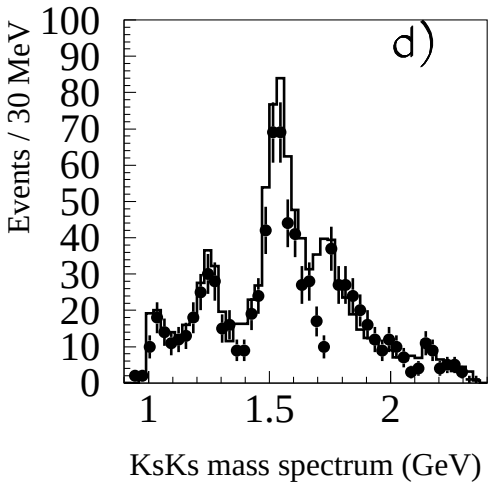
First tensor nonet only

No $f_2(1750)$





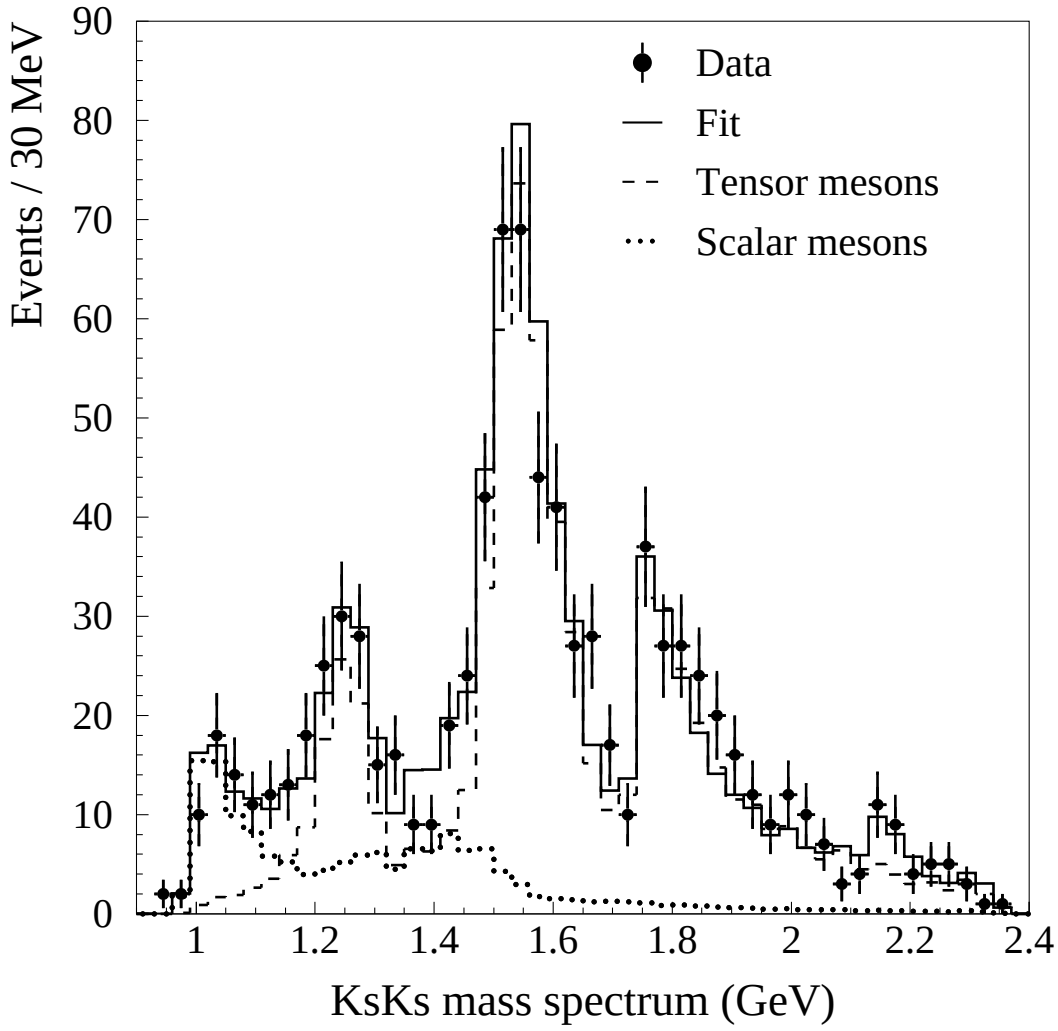




f_0 - like resonance instead of $f_2(1750)$
M=(1805±30) MeV
Γ=(260±30)MeV

$f_0(1710)$ with BES parameters

$K^0_s K^0_s$ mass fitted



- PWA favores a description of the peak at 1750 MeV by a tensor state.
- With nonet relations this state reveals as a solid member of a second tensor nonet together with $f_2(1560)$ and $a_2(1700)$.
- 4^{++} : M=(2150 ± 30) MeV, Γ=(50 ± 20) MeV.

$K^0_s K^0_s$ fit results

	First nonet			Second nonet		
	$a_2(1320)$	$f_2(1270)$	$f'_2(1525)$	$a_2(1700)$	$f_2(1560)$	$f_2(1750)$
Mass (MeV)	1304 ± 10	1277 ± 6	1523 ± 5	1730^*	1570^*	1755 ± 10
Width (MeV)	120 ± 15	195 ± 15	104 ± 10	340^*	160^*	67 ± 12
$K\bar{K}$ width (MeV)	$7.0^{+2.0}_{-1.5}$	7.5 ± 2	68^*	5 ± 3	2 ± 1	23 ± 7
Radius (fm)	0.55^*	0.55^*	0.5^*	0.55^*	0.55^*	0.5^*
Nonet coupling (MeV)	0.800 ± 0.1	0.9 ± 0.1	1.05 ± 0.1	0.38 ± 0.05		
Mixing angle (degrees)	-1 ± 3			-10^{+5}_{-10}		
$\gamma\gamma$ width (KeV)	0.91^*	2.55 ± 0.15	0.13 ± 0.03	0.18^*	0.50 ± 0.1	0.11 ± 0.04
$\pi\pi$ width (MeV)		148 ± 8	$0.2^{+1.0}_{-0.2}$		30^*	1.3 ± 1.0
$\pi\eta$ width (MeV)	18.5 ± 3			9.5 ± 2		
$\eta\eta$ width (MeV)		1.8 ± 0.4	5.0 ± 0.8		1.2 ± 0.3	2.0 ± 0.5

Consistent with previous L3 publication:
PL B 501 (2001) 173.

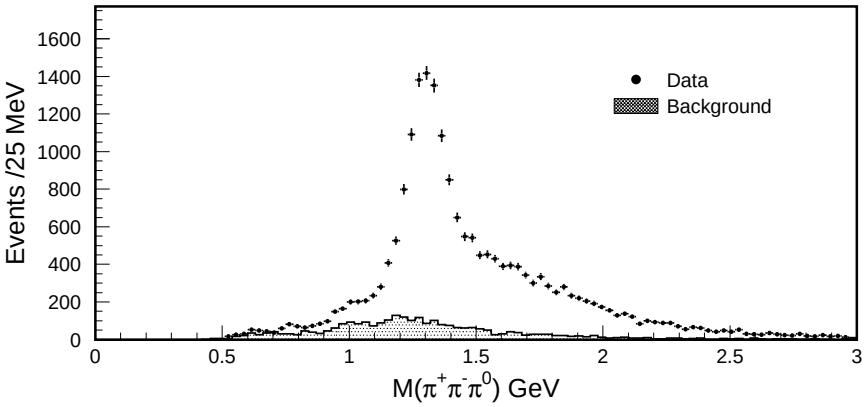
- Is the position of the tensor states an indication of a glueball?
  (tensor glueball, M=1800 - 2000 MeV).

$K^0_s K^0_s$ summary

We have performed a comprehensive investigation of the $\gamma\gamma \rightarrow K^0_s K^0_s$ data.

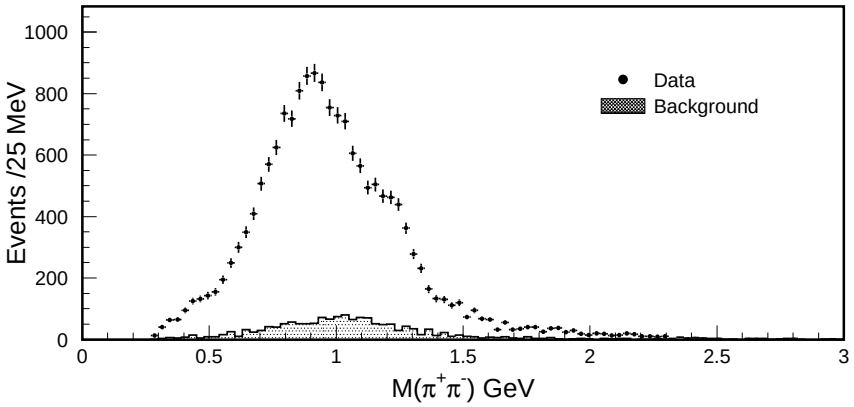
- Partial Wave Analysis favores a description of the peak at 1750 MeV by a tensor state $f_2(1750)$.
- If nonet relations are applied this state is revealed as a solid member of a second tensor nonet together with $f_2(1560)$ and $a_2(1700)$ states.
- The data define very well the mixing angles for two tensor nonets: (-1$\pm$3) for the first and (-10^{+5}_{-10}) for the second.
- There is an indication for 4^{++} state : M=(2150 ± 30) MeV, Γ=(50 ± 20) MeV.
- Indication of presence of tensor glueball with M=1800-2000 MeV.

$\pi^+\pi^-\pi^0$ - mass combinations



2^{++} : $a_2(1320)$, $a_2(1700)$, $a_2(2030)$; 2^{-+} : $\pi_2(1670)$

0^{-+} : π (1300)

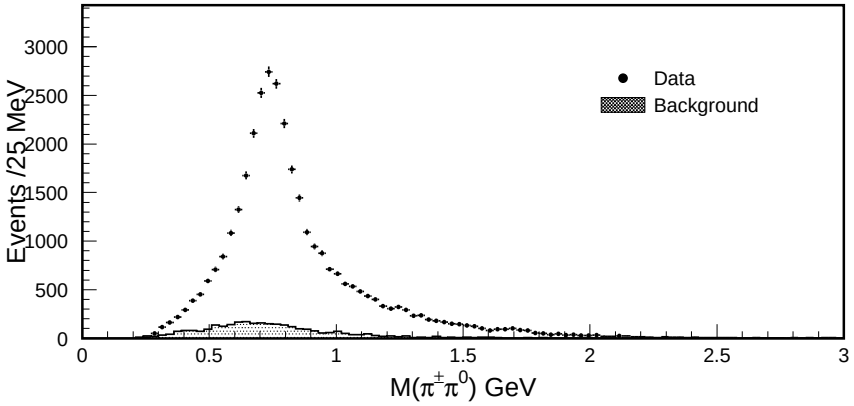


Only f-states: $J^{PC} = 0^{++}, 2^{++}, 4^{++}, ...$

2^{++} : $f_2(1270)$;

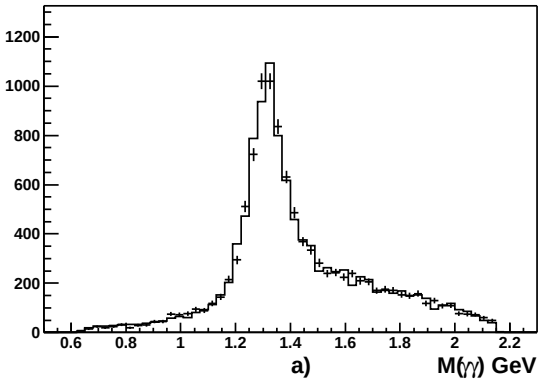
0^{++} : $f_0(980)$ and $f_0(1500)$ were omitted

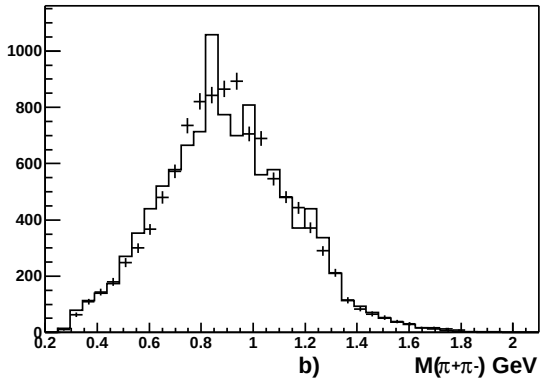
$\pi\pi$ S-wave amplitude (up to 2 GeV)

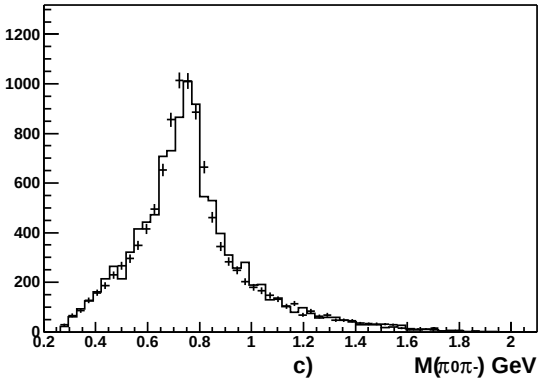


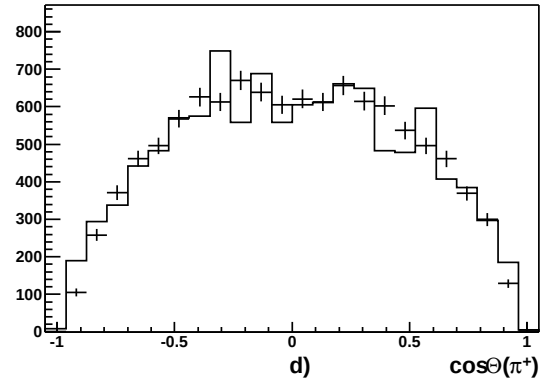
1^{--} : $\rho(770)$, $\rho(1450)$

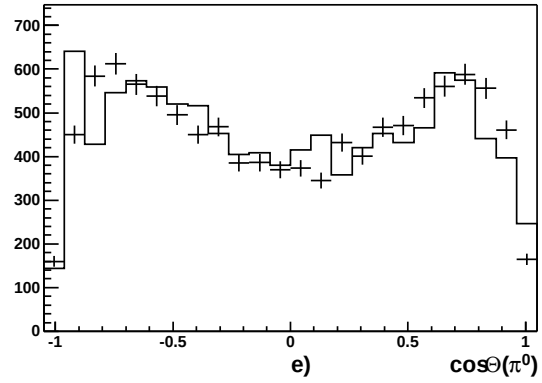
$\pi^+\pi^-\pi^0$ fit quality

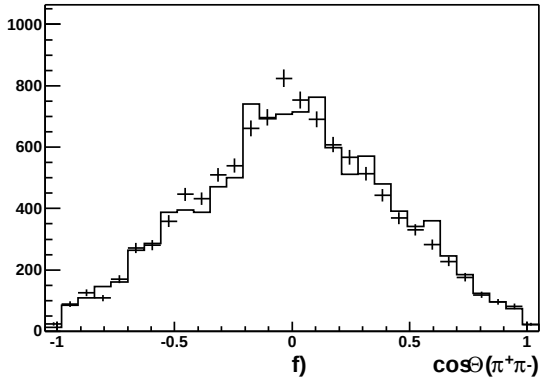








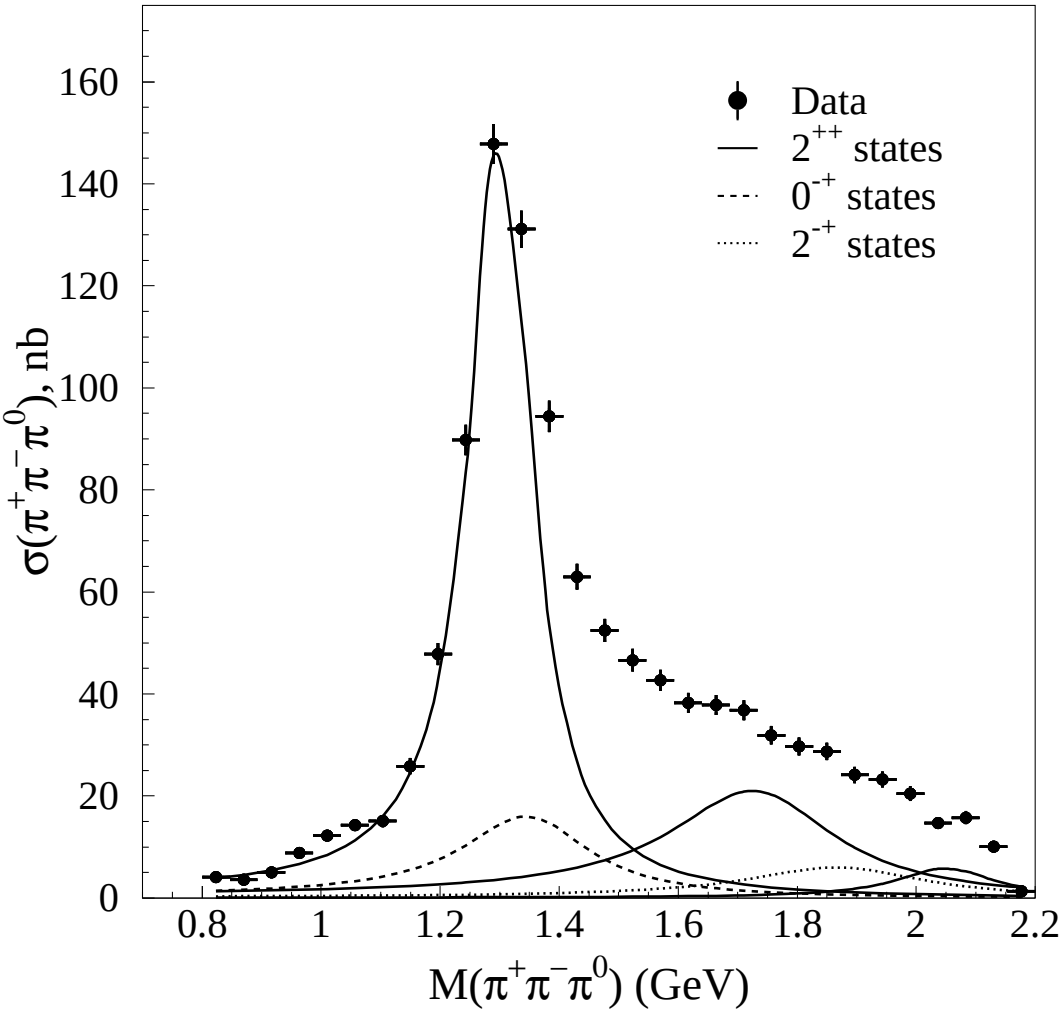




$\pi_2(1670)$ slightly deteriorates a likelihood.

2^{-+} : M = 1870±60, Γ = 325±40

$\pi^+\pi^-\pi^0$ mass : contribution of states



$\pi^+\pi^-\pi^0$ fit results

Resonance	M (MeV)	Γ(MeV)	$\Gamma_{\gamma\gamma}$Br(3π) (KeV)
$a_2(1320)$	$1302 \pm 3 \pm 6$	$118 \pm 6 \pm 10$	0.65 ± 0.05
$a_2(1700)$	$1725 \pm 25 \pm 10$	340 ± 40	$0.37^{+0.12}_{-0.08}$
$a_2(2030)^*$	2030 ± 20	205 ± 25	0.11 ± 0.04
$\pi(1300)$	1350 ± 40	320 ± 50	≤ 0.8
2^{-+}	1870 ± 60	325 ± 40	0.15 ± 0.03
$\pi_2(1670)^{**}$	1670	260	≤ 0.1

Consistent with previous L3 publication:
PL B 413 (1997) 147.

$a_2(1320)$:

$$\sigma(\gamma\gamma(^5S_2))/\sigma(\gamma\gamma(^1D_2)) = 8.2 \pm 0.6$$

$a_2(1700)$:

$$\sigma(\gamma\gamma(^5S_2))/\sigma(\gamma\gamma(^1D_2)) = 2.5 \pm 1.0$$

$\pi^+\pi^-\pi^0$ summary

- The characteristics of the dominant $a_2(1320)$ state are found.
- Strong signal is observed from the first radial excitation of isovector tensor state $a_2(1700)$:
  M $= 1725 \pm 25 \pm 10$ MeV, $\Gamma = 340 \pm 40$ MeV.
- Another isovector state with the mass 2030 MeV is found to be significant.
- There is also a signal from $\pi(1300)$ and an indication for a 2^{-+} signal in the region of 1870 MeV .