$K^0_s K^0_s$ Final State in Two-Photon Collisions and Glueball Searches

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L3 Collaboration

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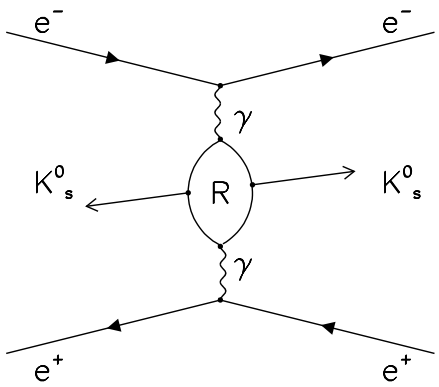
Outline

- Meson Resonances in Two–photon physics
- The Glueballs
- The L3 Detector
- Event Selection
- The $f_2'(1525)$ tensor meson
- The 1750 MeV region
- The $\xi(2230)$ glueball candidate
- Conclusions

Production of mesons in Two–photon physics

- Very clean final state w.r.t. hadronic production
- Production rate calculated by QED
- Final state quantum numbers restricted by $\gamma\gamma$

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



Outgoing $\mathrm{e}^+\mathrm{e}^-$ are undetected ("No Tag")

$\Rightarrow$ Quasi-real photons

R neutral unflavoured meson with $C = +1$ and $J \neq 1$

$\mathrm{K}^0_s\mathrm{K}^0_s$ final state

$\Rightarrow J^{PC}$=(even)$^{++}$

0^{++} and 2^{++} States

The cross section for the process

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

can be written as

$$\sigma(e^+e^- \rightarrow e^+e^- R) = \int d^5\mathcal{L}(\alpha_i) \cdot \sigma(\gamma\gamma \rightarrow R)$$

The Luminosity Function $\mathcal{L}(\alpha_i)$ is calculable by QED and

$$\sigma(\gamma\gamma \rightarrow R) = 8\pi(2J+1)\frac{\Gamma_{\gamma\gamma}\Gamma_R}{(m_R^2 - W_{\gamma\gamma}^2)^2 + m_R^2\Gamma_R^2}$$

where :

J	Spin
m_R	Mass
$\Gamma_{\gamma\gamma}$	Two–photon width
Γ_R	Total width
$W_{\gamma\gamma}$	Two–photon system invariant mass

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

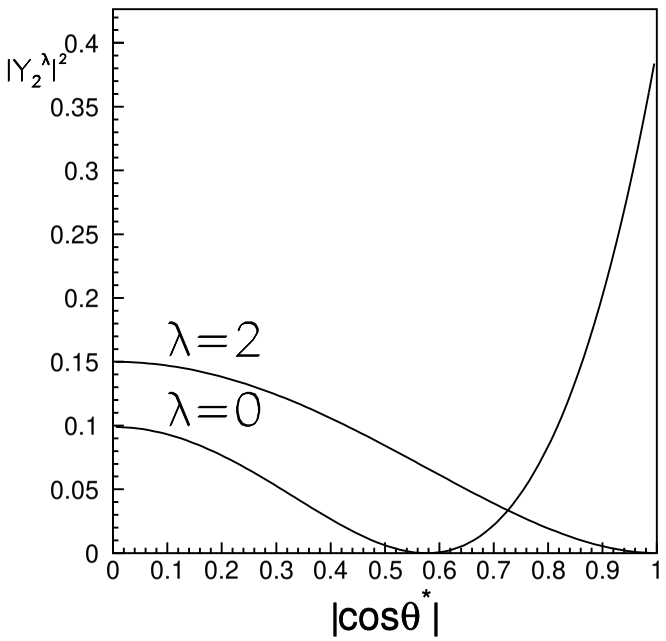
$$J^{PC} = 2^{++}$$

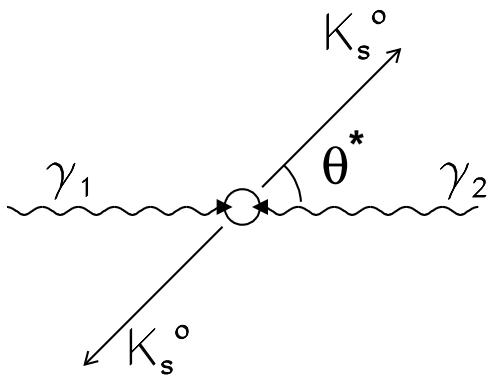
- Neutral members :

$$a_2(1320)\ \ f_2(1270)\ \ f_2'(1525)$$

- $f_2 - a_2$ interference : destructive in $K^0\bar{K}^0$, constructive in K^+K^- (H.J.Lipkin,Nucl.Phys.B7(1968)321)

- Helicity 0 or 2 $\Rightarrow$ Different angular distributions!





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

The identification of the neutral constituents of the scalar nonet is more complicated due to a lot of broad and interfering resonances in the mass range 1.– 1.5 GeV.

Recently the Crystal Barrel Collaboration at LEAR discovered 3 new 0^{++} neutral states :

$$a_0(1450)\ f_0(1370)\ f_0(1500)$$

The $f_0(1370)$ and the $f_0(1500)$ are incompatible with a $s\bar{s}$ state and cannot be both $u\bar{u} + d\bar{d}$.

There are too many states to fit in a nonet!

Some of these resonances could be interpreted as Glueballs

QCD is a non–abelian gauge theory:

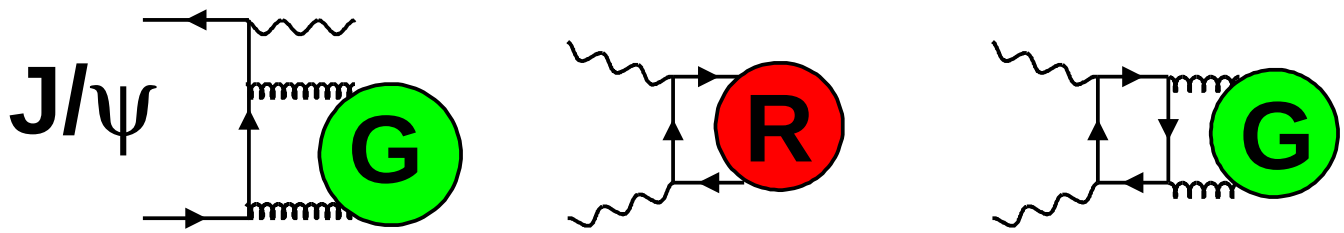
- Gluon-Gluon interactions
- Glueballs are gluons bound states
- Mixing between glueballs and $q\bar{q}$ states is possible

Glueballs signature:

- Flavour blind decay branching ratios
- Gluons are neutral $\Rightarrow \Gamma_{\gamma\gamma}$ very small

Two–photon interactions are a tool to identify a Resonance as a Glueball or a Meson

Glueballs are produced in gluon rich environments like $p\bar{p}$, pp collisions and radiative J/ψ decays.



Direct experimental evidence for glueballs is still not clear.

Lattice QCD predictions:

- 0^{++} ground state M=1600 $\pm$ 200 MeV, $\Gamma \simeq 100$ MeV
- 2^{++} tensor state $M_{2^{++}}/M_{0^{++}} \simeq 1.5 \rightarrow M \simeq 2200$ MeV

The understanding of the $q\bar{q}$ mass spectrum is crucial in the search for glueballs.

0^{++} Glueballs

According to C.Amsler and F.E.Close:

State	Isospin		
$a_0(1450)$	1	✔	
$f_0(1370)$	0	✔	
$f_0'(1500\text{-}1800)$	0		$s\bar{s}$?
$f_0(1500)$	0	✔	Glueball ?

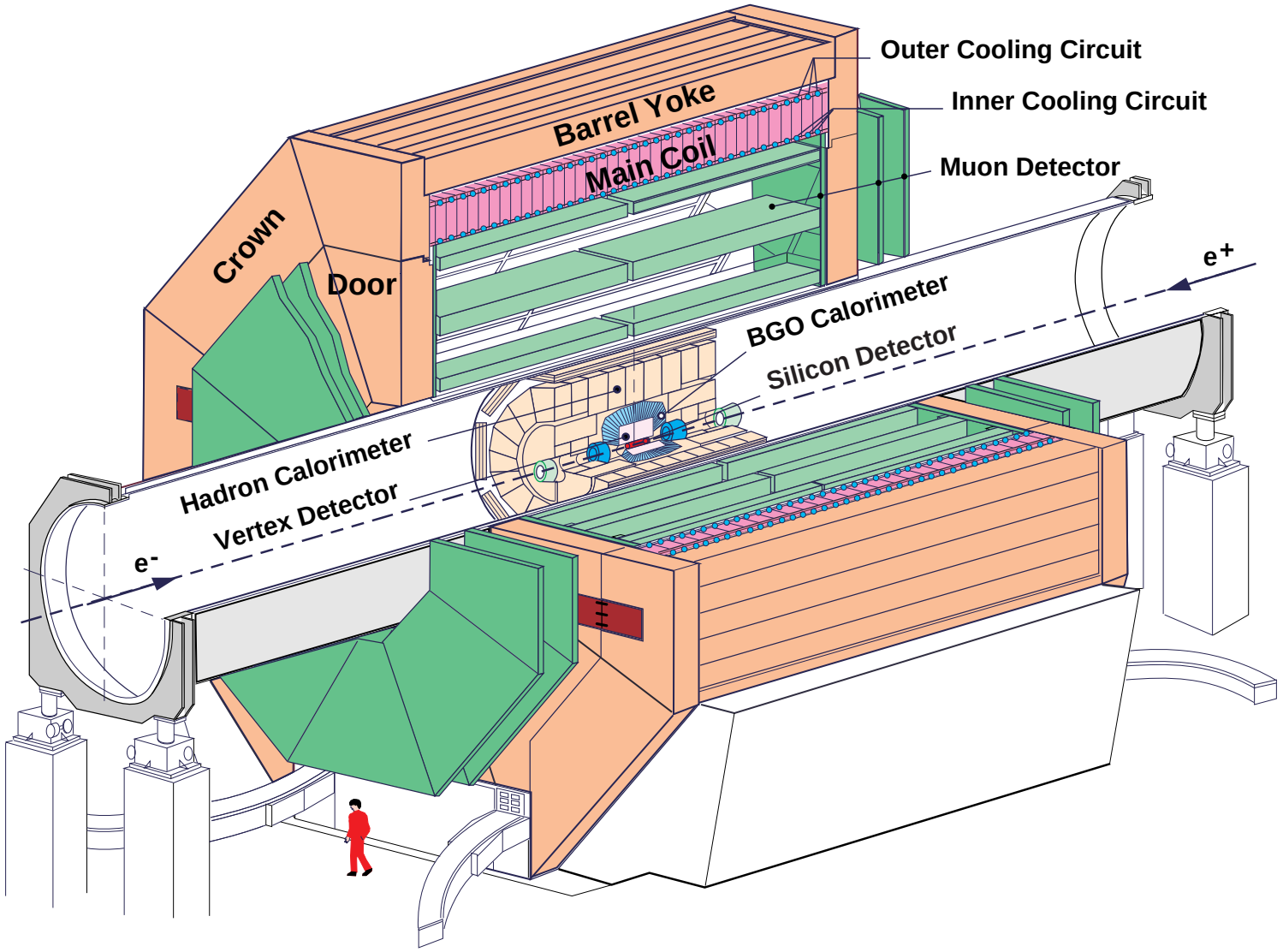
The $f_0'(1500-1800)$ is expected to be $s\bar{s}$ and to couple strongly to $K\bar{K}$

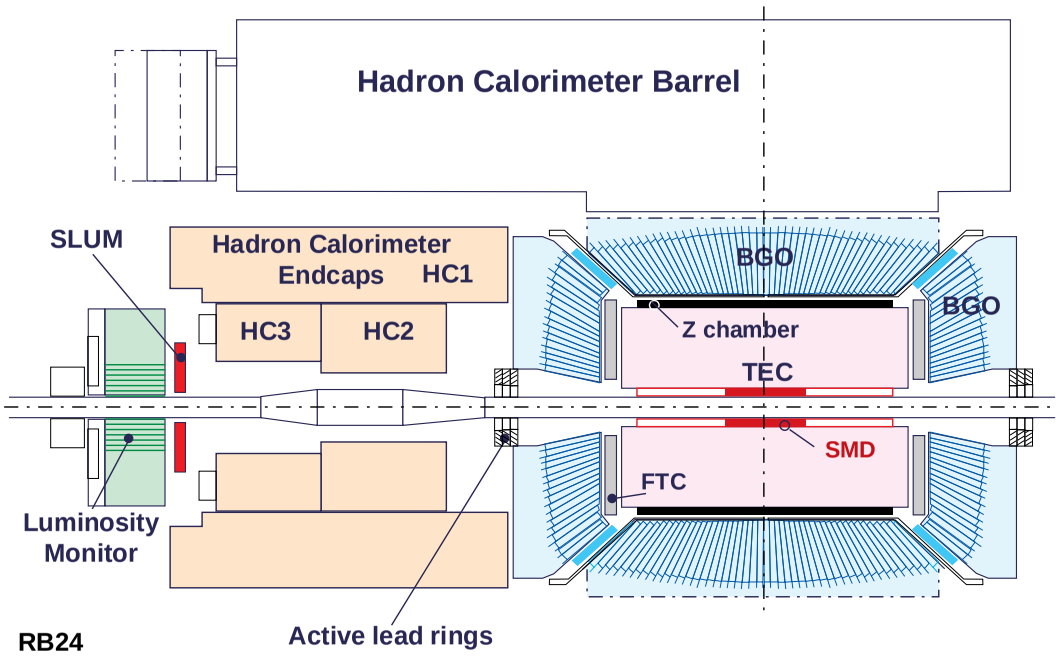
2^{++} Glueballs

Observation of $\xi(2230)$ in J/ψ radiative decays (Mark III, BES Collaboration)

- in K^+K^-, $K_s^0K_s^0$, $\pi^+\pi^-$ and $p\bar{p}$ final states
- Very narrow : Γ=20 MeV
- Seems to have flavour blind coupling

Search for it in two–photon collisions


Outer Cooling Circuit
Inner Cooling Circuit
Muon Detector
Barrel Yoke
Main Coil
Crown
Door
BGO Calorimeter
Silicon Detector
Hadron Calorimeter
Vertex Detector
e+
e-



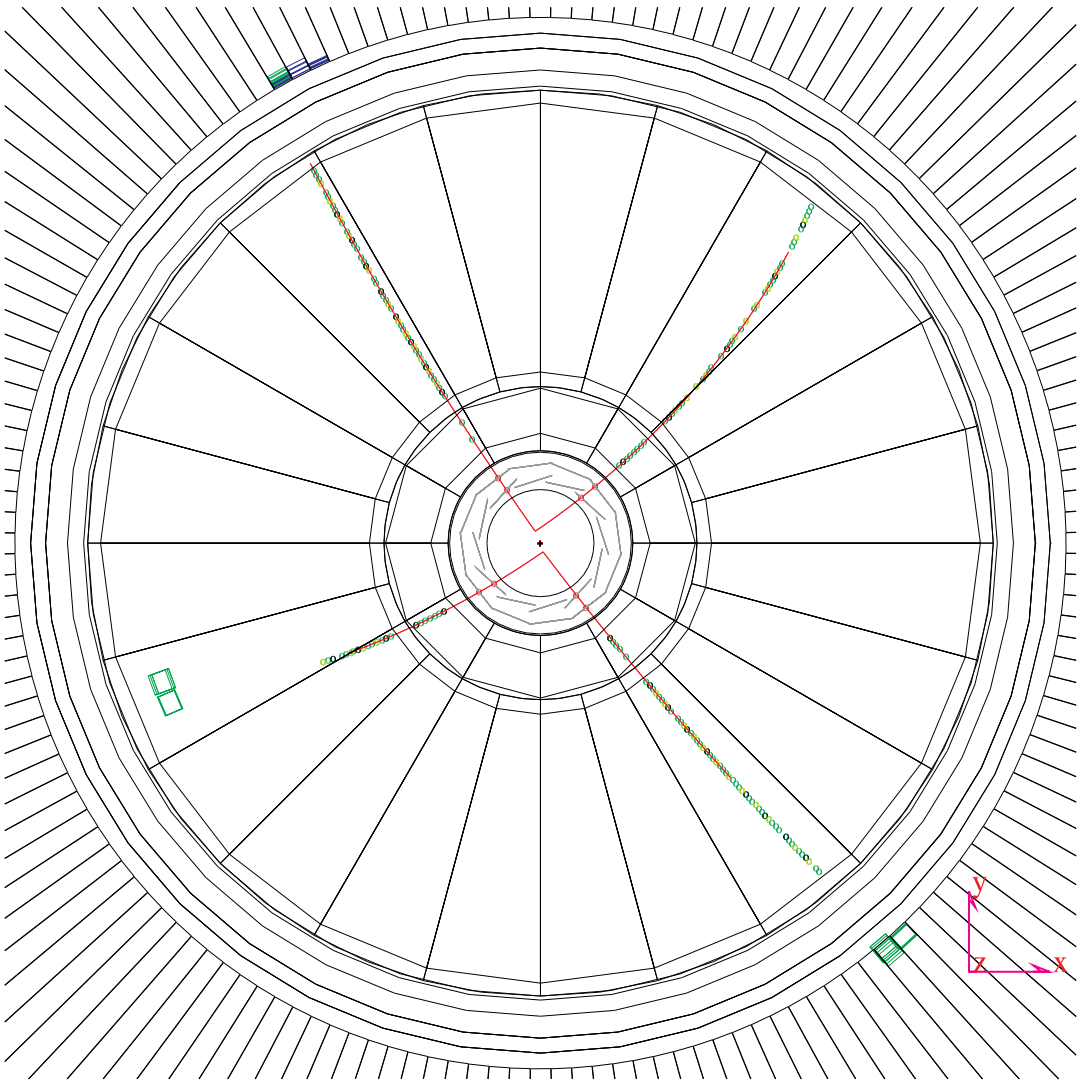
- Central tracking system : Silicon Microvertex Detector + Time Expansion Chamber
- Electromagnetic Calorimeter : BGO - High resolution (5% at 100 MeV, 1.4% above 2 GeV)
- Charged-track Trigger : Low p_T threshold $\sim$150 MeV

Data sample

	$\sqrt{s}$	$\mathcal{L}$ (pb^{-1})
LEP I	$M(Z)$	143
LEP II	183 GeV	52
	189 GeV	172

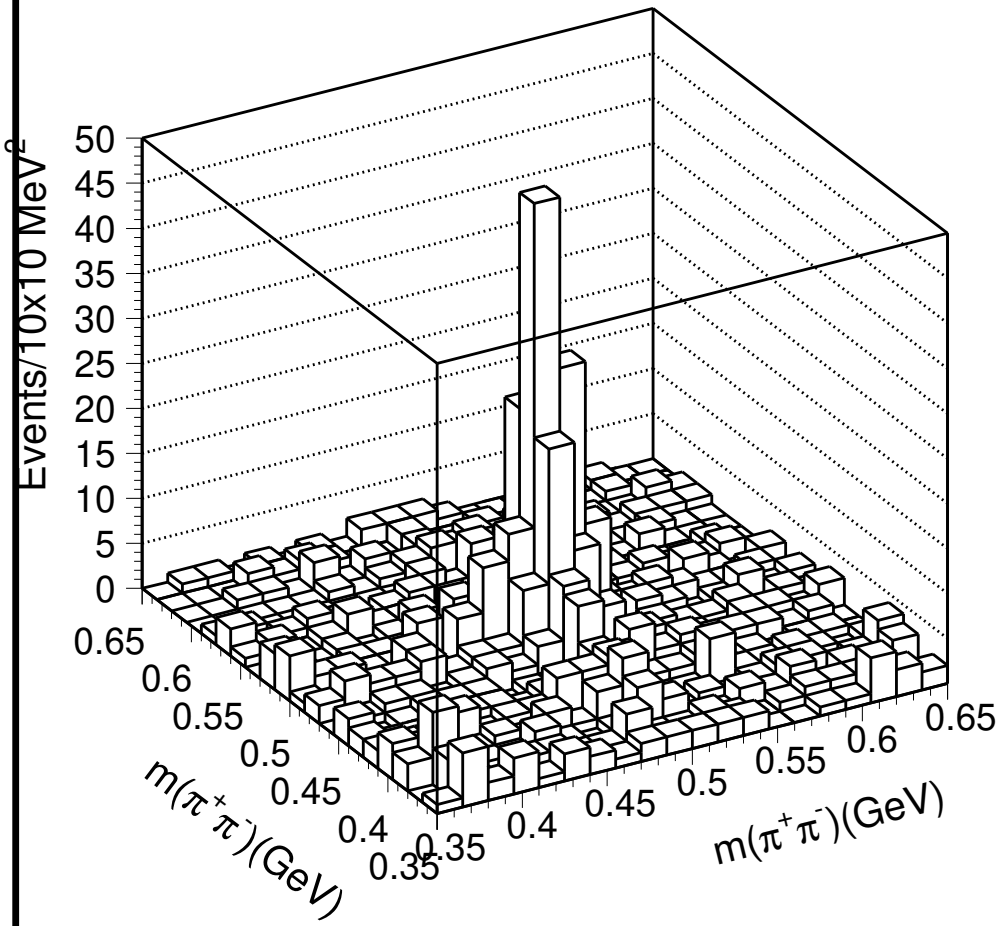
$\gamma\gamma \rightarrow K^0_s K^0_s$ event

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

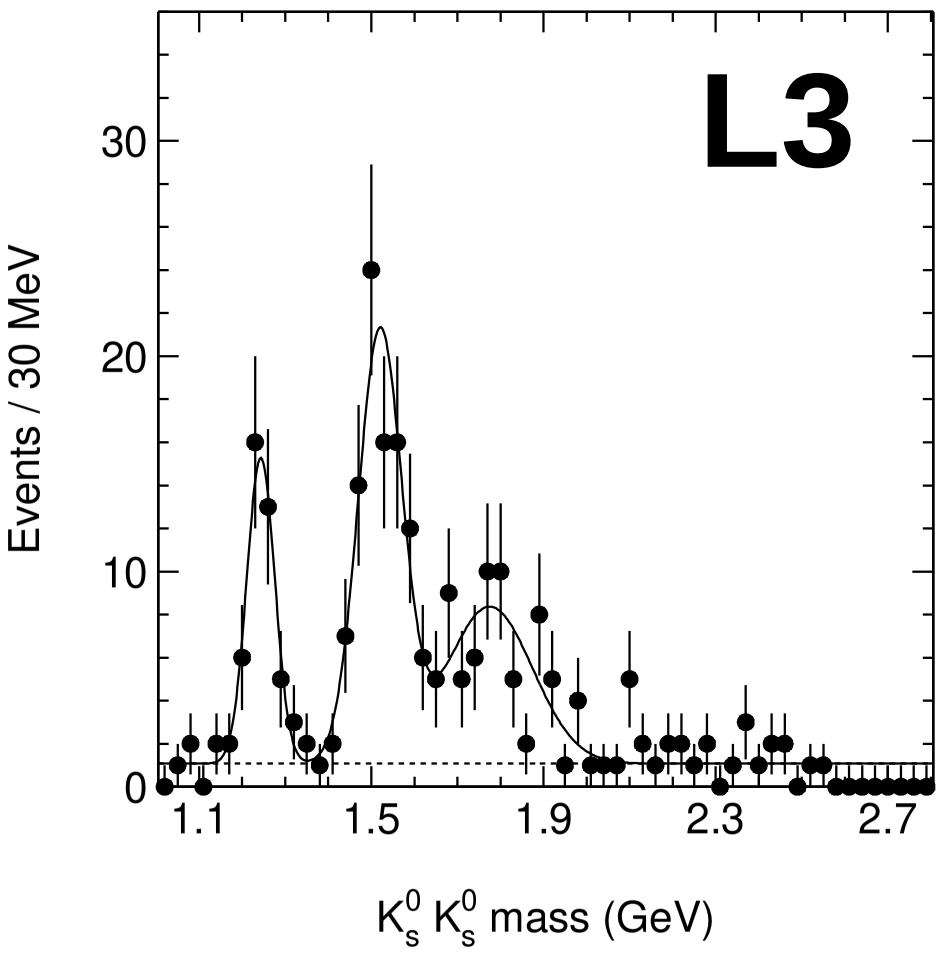


Only $K^\circ_s \rightarrow \pi^+\pi^-$ final states are selected

The $K^0_s K^0_s$ Final State



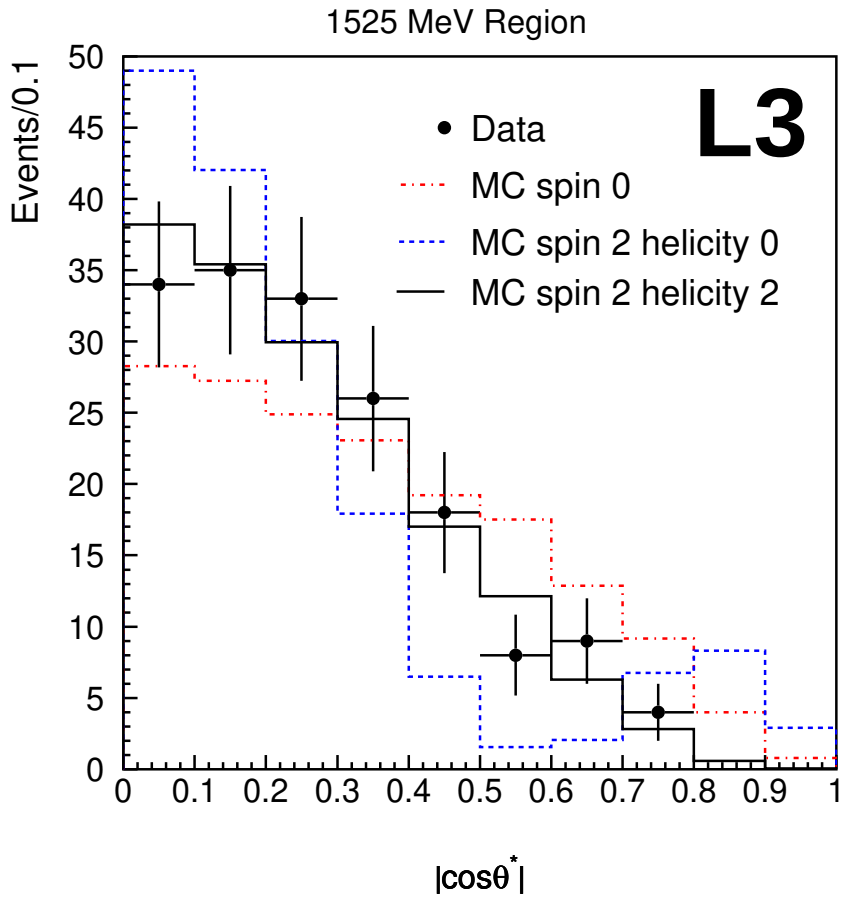
- 4 charged tracks
- Secondary vertices with DCA>1 mm
- No photons
- K^0_s direction & $\vec{P}_t(\pi^+\pi^-)$ matching
- small Transverse Momentum Imbalance
- $M_{\pi^+\pi^-} \simeq M_{K^0_s} \pm 40\ MeV$



	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 around 1750 MeV
- No signal in the $\xi(2230)$ region

The $f_2'(1525)$ State

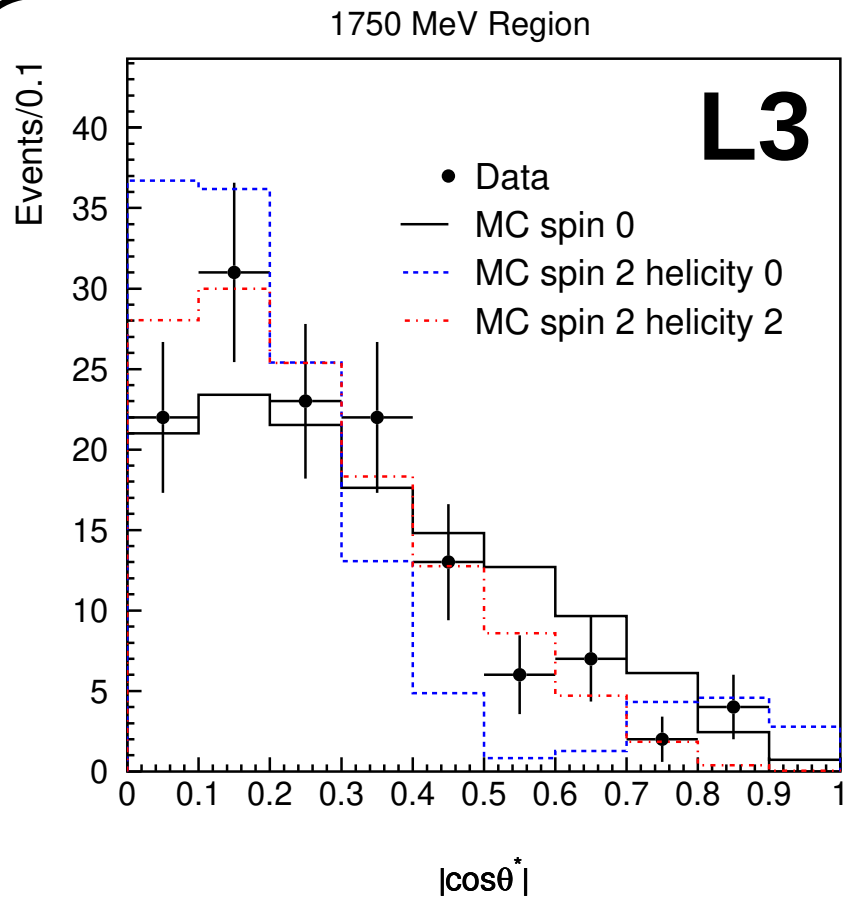


χ^2(9 d.o.f.)		
J=0		22.5
J=2,	λ=0	28.5
J=2,	λ=2	**4.2**

Detection efficienty for helicity 2 is 7.6% at LEP1 and 6.4% at LEP2

Helicity λ=2 dominates

$$\Gamma_{\gamma\gamma}(f_2') \times \mathrm{BR}(K\bar{K}) = (0.08 \pm 0.02)\text{k eV}$$



χ^2(9 d.o.f.)		
J=0		17.9
J=2,	λ=2	7.2
J=2,	λ=0	26.3

More statistics in needed for the helicity determination

Interpretation of the resonance

$f_2'(1525)$ radial recurrence, $f_2''(1740)$, $f_2'''(1820)$ (OGE-SRM prediction)
(C.R.Münz,Nucl.Phys.A609(1996)364.)

0^{++} $s\bar{s}$ state (C. Amsler & F. Close)

The $\Gamma_{\gamma\gamma}(\xi(2230))$

- The experimental resolution for the $\xi(2230)$ is σ=60 MeV
  $\rightarrow$ signal region : $M_{\xi(2230)} \pm 2\sigma$
- The background is estimated by fitting the sidebands
- J=2, λ=2 are assumed

Data Sample	Events in Signal Region	Expected Background	Detection Efficiency	95% Events	C.L. Upper Limits $\Gamma_{\gamma\gamma}(\xi)Br(K^0_sK^0_s)$
LEP I	6	4.9	16.6%	7.3	4.1 eV
LEP II (97)	2	7.9	15.2%	3.6	4.2 eV
LEP II (98)	13	18.9	14.1%	6.5	2.5 eV

Combining the three results by Monte Carlo :

$$\boldsymbol{\Gamma_{\gamma\gamma}(\xi) \times Br(\xi \rightarrow K^0_sK^0_s) < 1.5} \text{ eV at 95\% C.L.}$$

The ratio between the coupling to gluons respect to photons is expected to be very large for glueballs. This is experessed by the stickiness

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

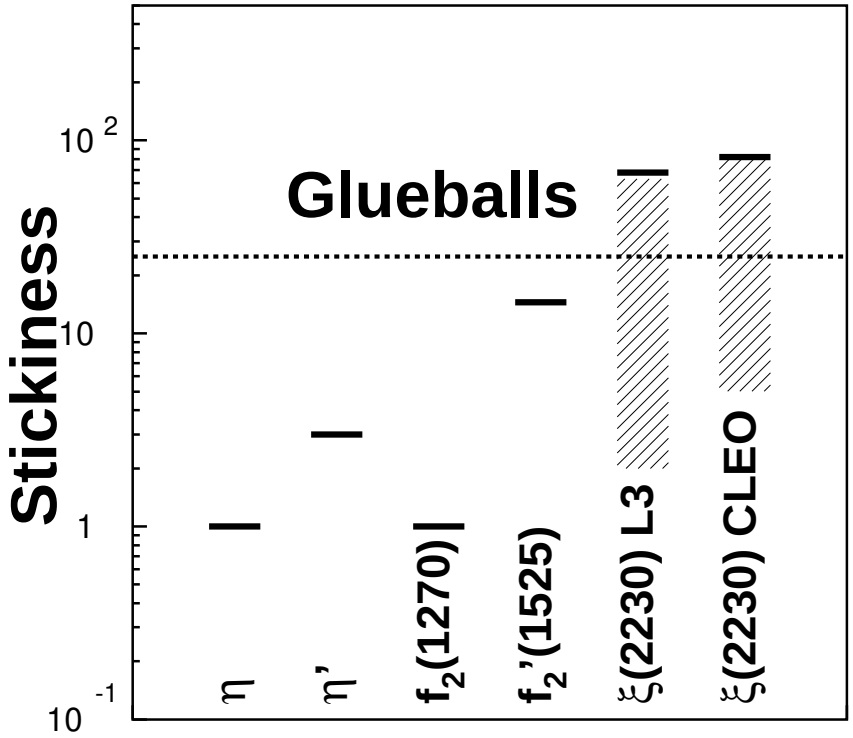
where:

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 result by BES and Mark III
$\Gamma(J/\psi \to \xi\gamma) Br(\xi \to K^0_s K^0_s)$=(2.2±0.6)×$10^{-5}$
with our upper limit
$\Gamma(\xi \to \gamma\gamma) Br(\xi \to K^0_s K^0_s)$ <1.5 eV at 95% C.L.
we obtain

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

Errors are taken into account by a Monte Carlo calculation.



- The $f_2'(1525)$ is nearly a pure $s\bar{s}$ state. $S_{f_2'(1525)}$=14.7
- Due to its stickiness and its width, the $\xi(2230)$ is a good glueball candidate, according to lattice QCD theoretical predictions.

Conclusions

$K^0_s K^0_s$ final state in Two–photon processes

- $f'_2(1525)$ tensor meson in helicity 2 state
- $f_2 - a_2$ destructive interference
- Enhancement of 7σ in the 1750 MeV region:
  - ➥ radial recurrence of the f'_2 (1525)?
  - ➥ 0^{++} $s\bar{s}$ state?
- No signal for the $\xi(2230)$
  - ➥ $\Gamma_{\gamma\gamma} \times \mathrm{BR}(\xi \to K^0_s K^0_s)$ <1.5 eV
  - ➥ Stickiness $(\xi) > 68$ at 95% C.L.
- More data from LEP2 are needed in order to give more significant contribution to the glueball searches