The $K^0_s K^0_s$ Final State in Two-Photon Collisions and Some Implications for Glueball Searches

Saverio Braccini
University of Geneva

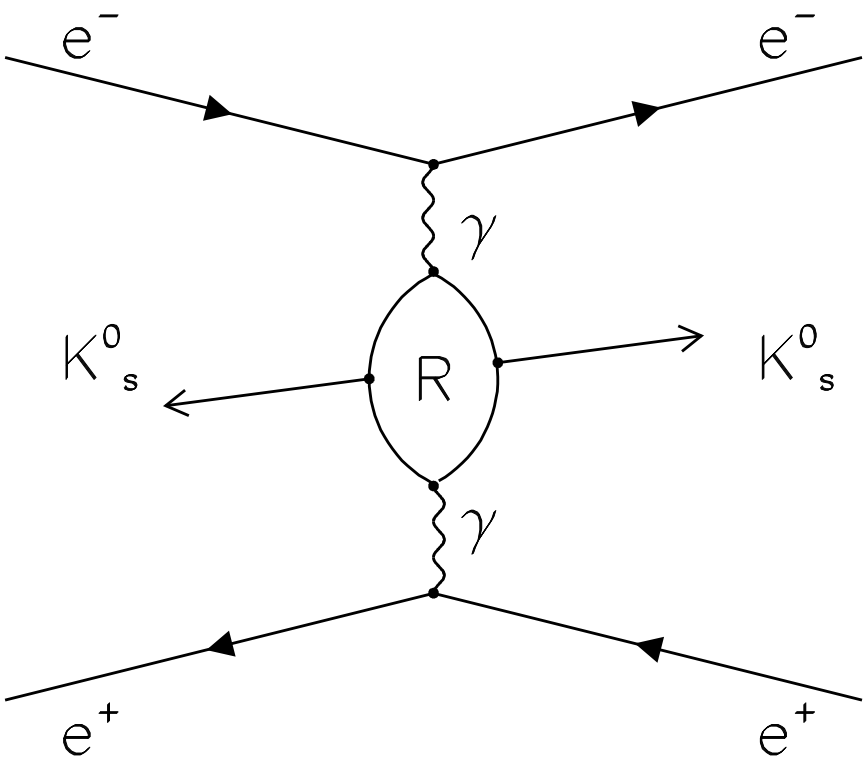
representing the
L3 Collaboration

LEAP98
Villasimius, Italy, September, 1998.

Outline

- Introduction
- LEP and the L3 Detector
- Event Selection
- The $f_2'(1525)$ tensor meson
- The 1750 MeV region
- The $\xi(2230)$ glueball candidate
- Conclusions & Outlook

Resonance Formation



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

- Outgoing e^+e^- are undetected ("No Tag")
  $\rightarrow$ Quasi-real photons
- R neutral unflavoured meson with C=+1
- $K^0_s K^0_s$ final state $\rightarrow$ J^{PC}=(even)$^{++}$

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

The Cross Section

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 QED calculable and

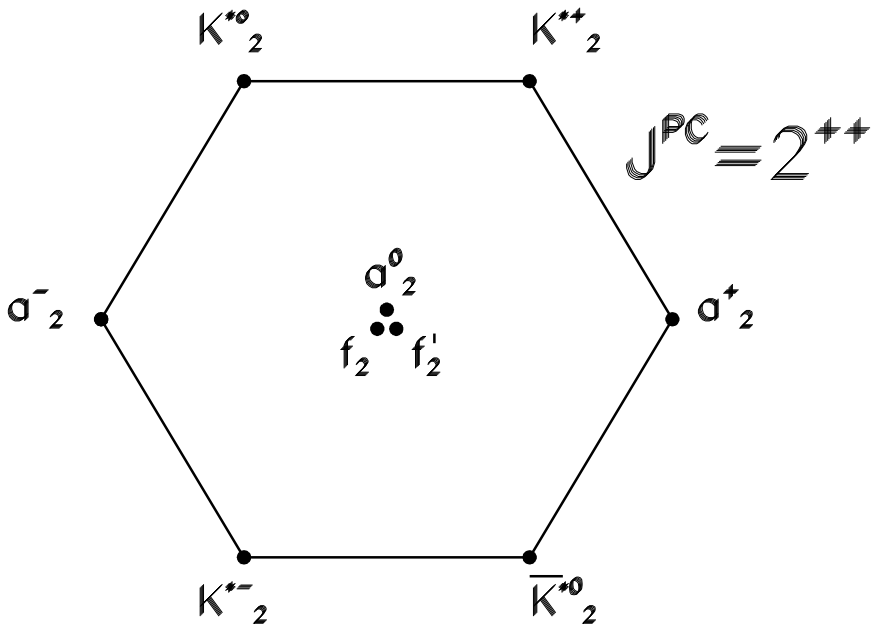
$$\sigma(\gamma\gamma \rightarrow R) = 8\pi(2J+1)\frac{\Gamma_{\gamma\gamma}\Gamma_R}{(m_R^2 - W_{\gamma\gamma}^2)^2 + m_R^2\Gamma_R^2}$$

where :

J	Spin
m_R	Mass
$\Gamma_{\gamma\gamma}$	Two-photon width
Γ_R	Total width
$W_{\gamma\gamma}$	Mass of the two-photon system

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

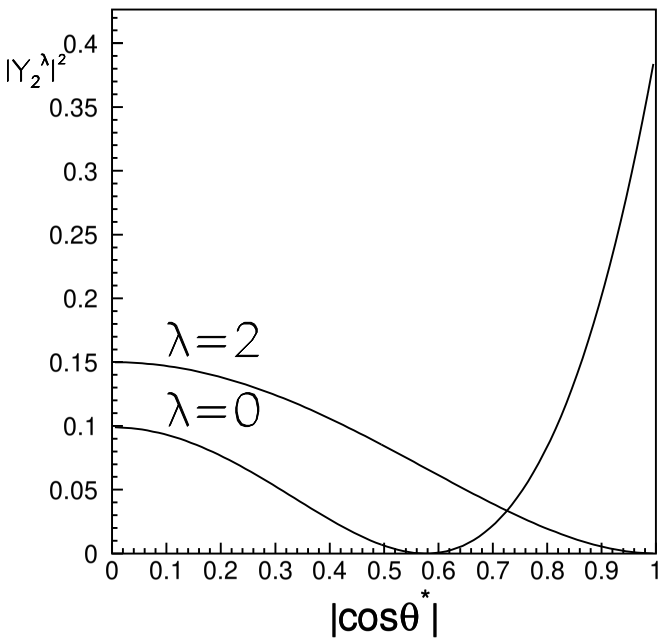
The Tensor Meson Nonet

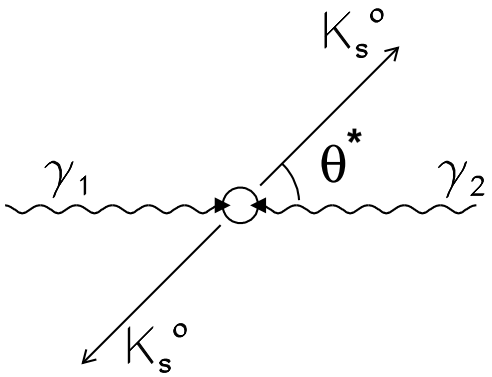


- Neutral members :

$$a_2(1320)\ f_2(1270)\ f'_2(1525)$$

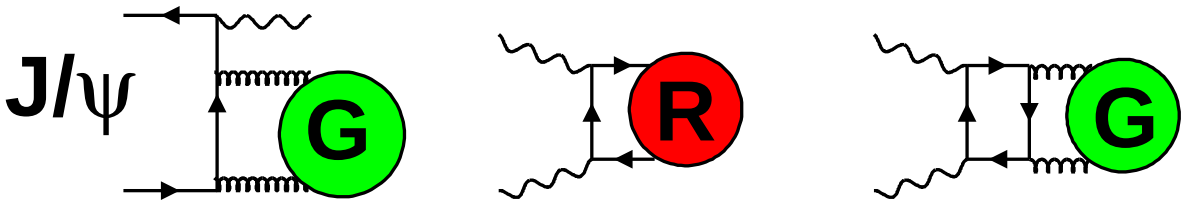
- $f_2 - a_2$ interference : destructive in $K^0\bar{K}^0$, constructive in K^+K^- (H.J.Lipkin,Nucl.Phys.B7(1968)321)
- Helicity 0 or 2 → Different angular distributions!





QCD is a non-abelian gauge theory :

- gluon-gluon interactions
- Bound states of two or more gluons
  $\Rightarrow$ Glueballs
- $q\bar{q}$/glueball mixing is possible



Properties of glueballs :

- produced in gluon rich environments like $p\bar{p}$, pp collisions and radiative J/ψ decays
- Flavour blind decay branching ratios
- Gluons are neutral

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

QCD is very well established but a direct experimental evidence for glueballs is still not clear.

There are many experimental and theoretical hints.

Lattice QCD predictions :

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

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

Two-photon interactions are a fundamental tool to distinguish mesons from glueballs

0^{++} Glueballs

Recently the Crystal Barrel Collaboration at LEAR discovered 3 new 0^{++} 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 $u\bar{u} + d\bar{d}$.

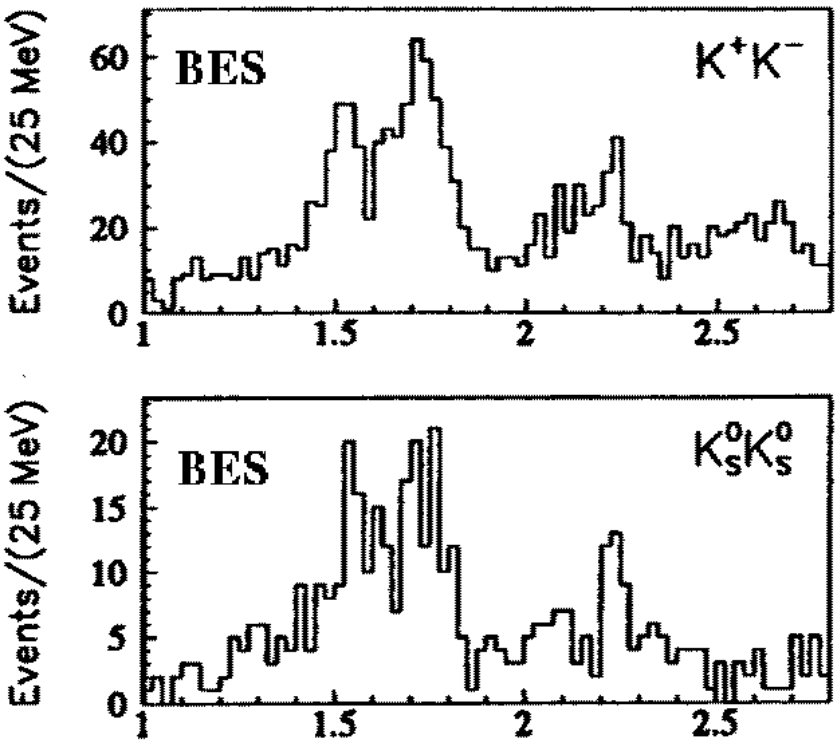
There are too many states to fit in a nonet!

According to C.Amsler and F.E.Close :
(Phys.Rev. D53(1996)295)

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

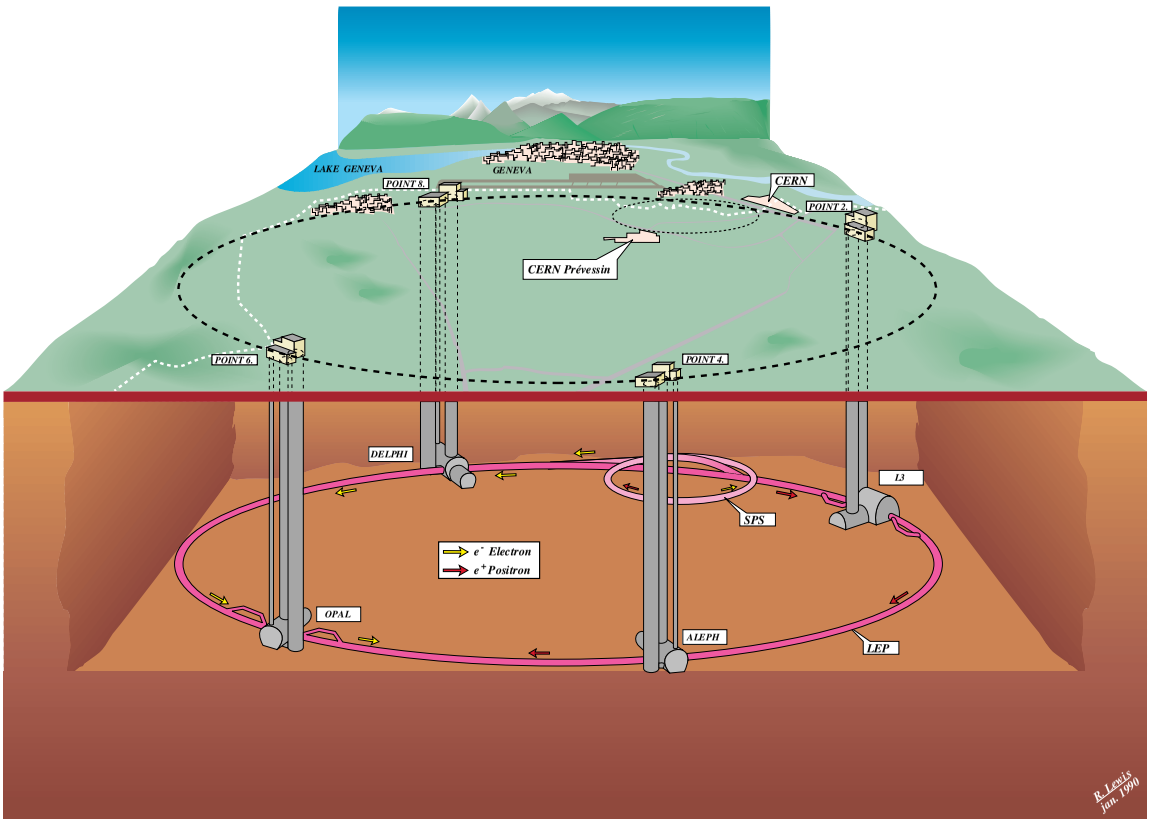
The BES Collaboration confirmed the observation of the $\xi(2230)$ in J/ψ radiative decays.



(Phys.Rev.Lett. 76(1996)3502)

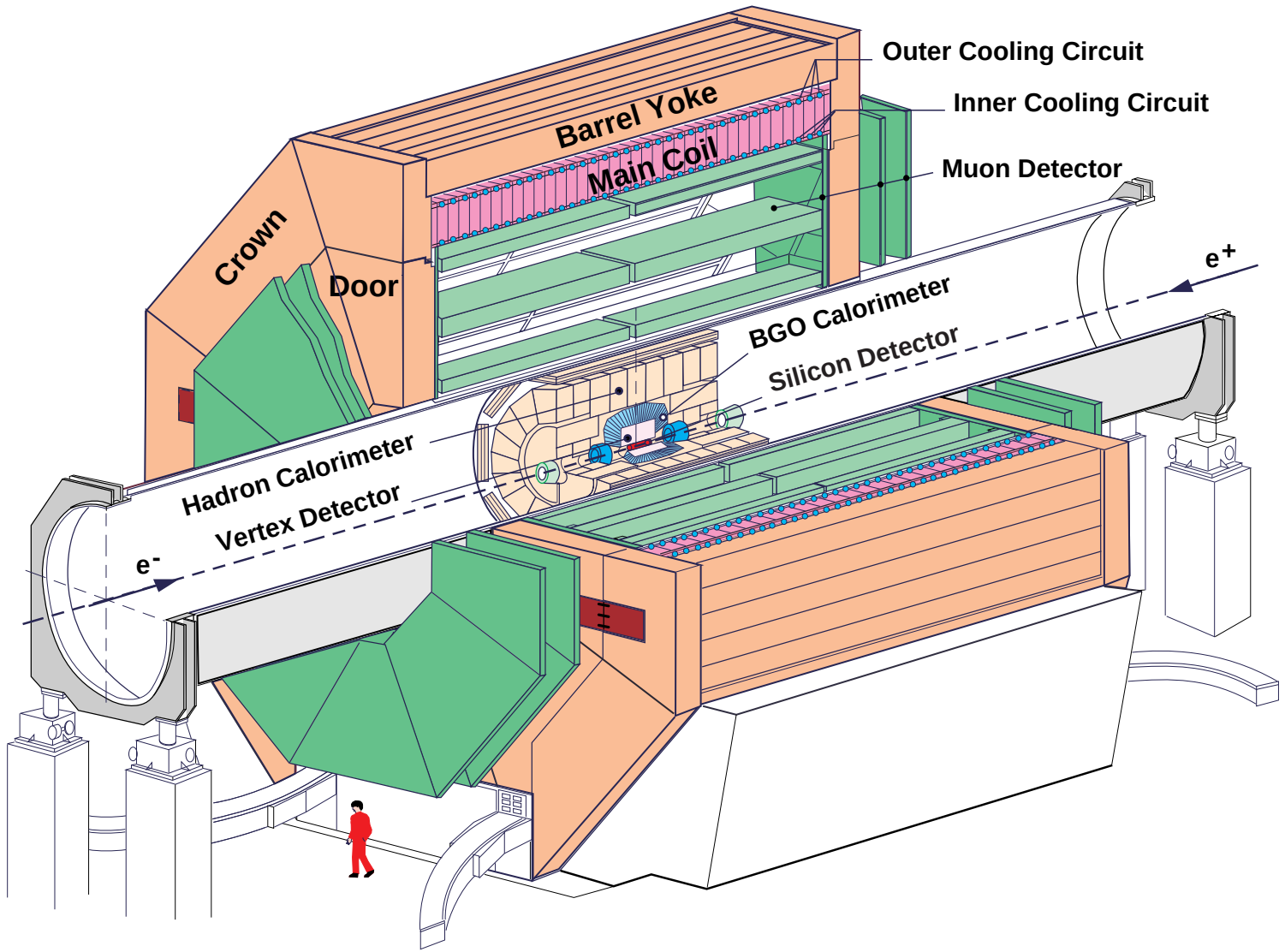
- Previously observed by Mark III
- Observed in K^+K^-, $K^0_sK^0_s$, $\pi^+\pi^-$ and $p\bar{p}$ final states
- Very narrow : Γ=20 MeV
- Seems to have flavour blind coupling

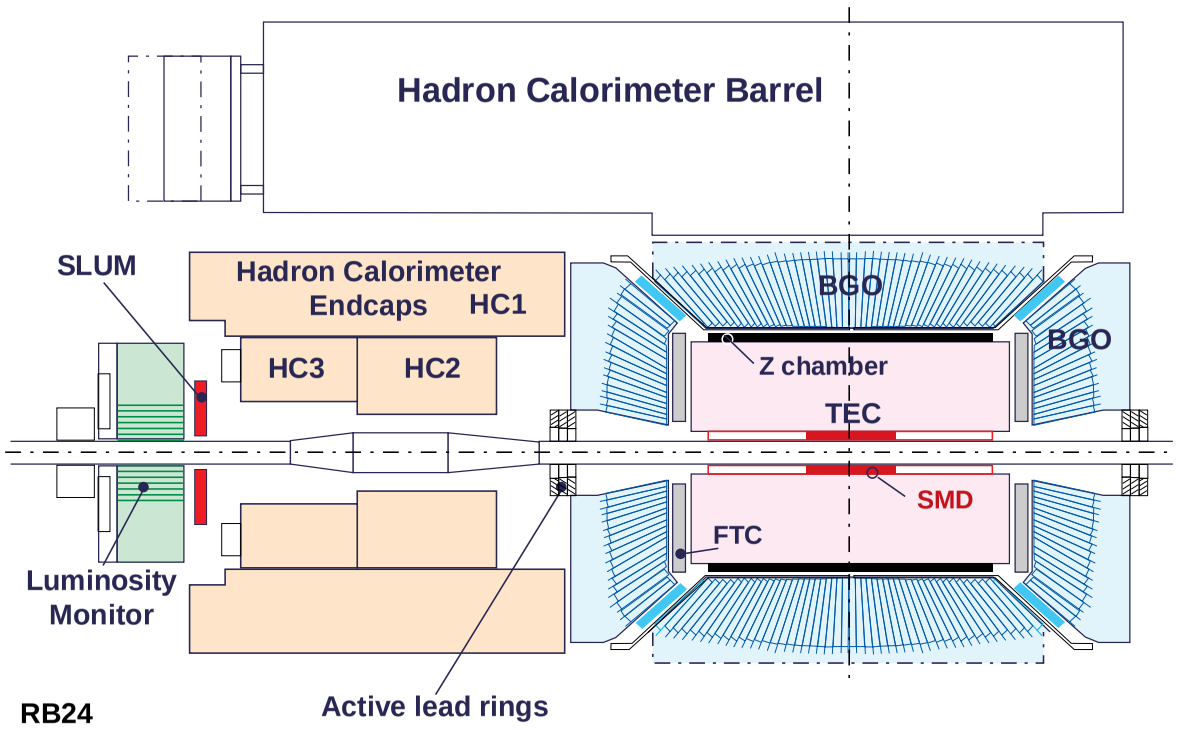
Is it visible in two-photon collisions ?



- LEP I $\sqrt{s} \simeq$m(Z) $\mathcal{L} = 143$ pb^{-1}
- LEP II $\sqrt{s}$=183 GeV $\mathcal{L} = 52$ pb^{-1}

The L3 Detector



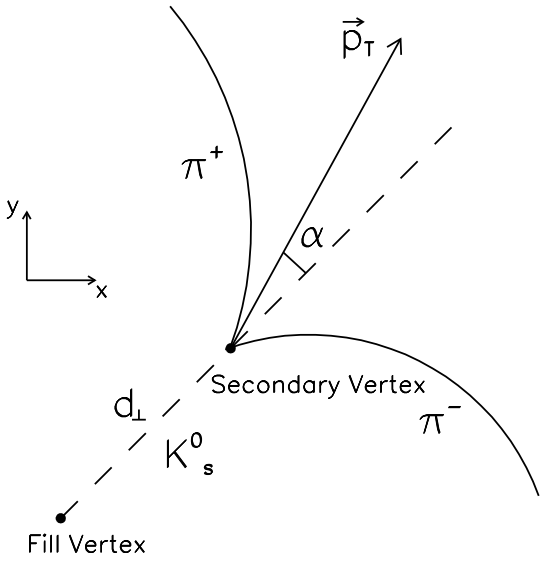


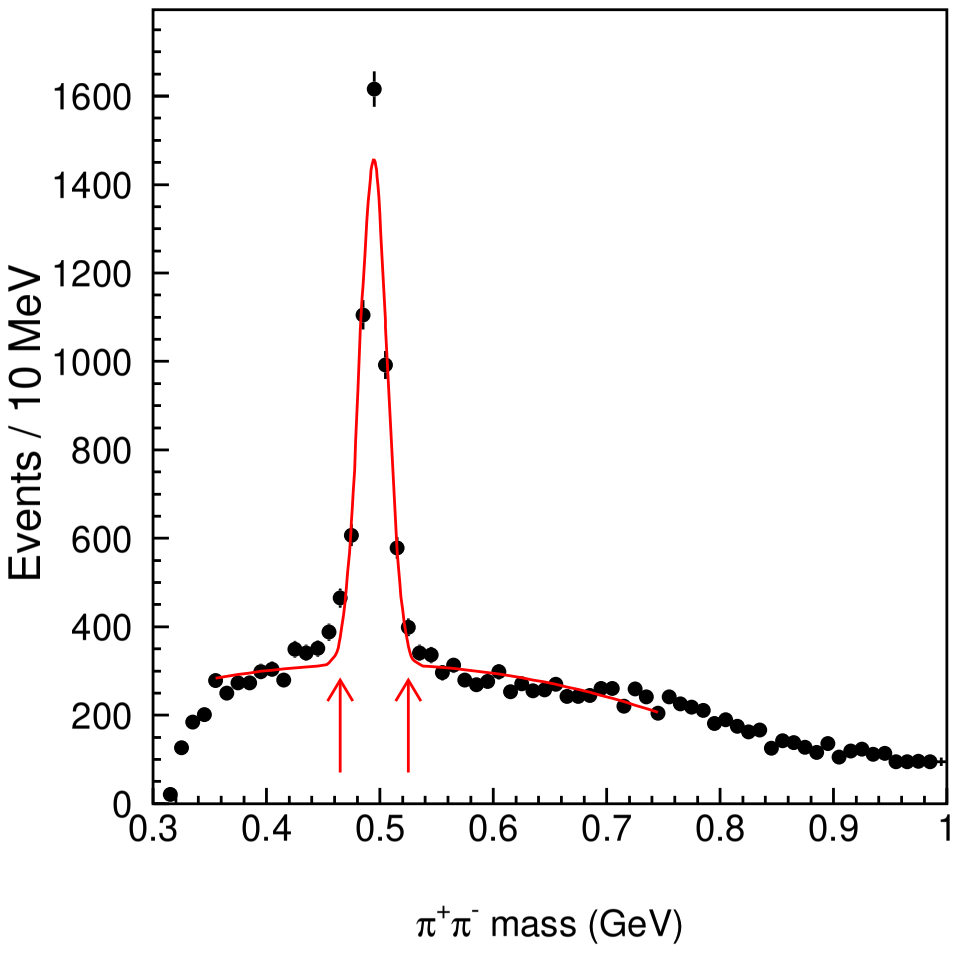
Devices mainly used for $\gamma\gamma \rightarrow$Resonance studies:

- 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

The K^0_s Selection

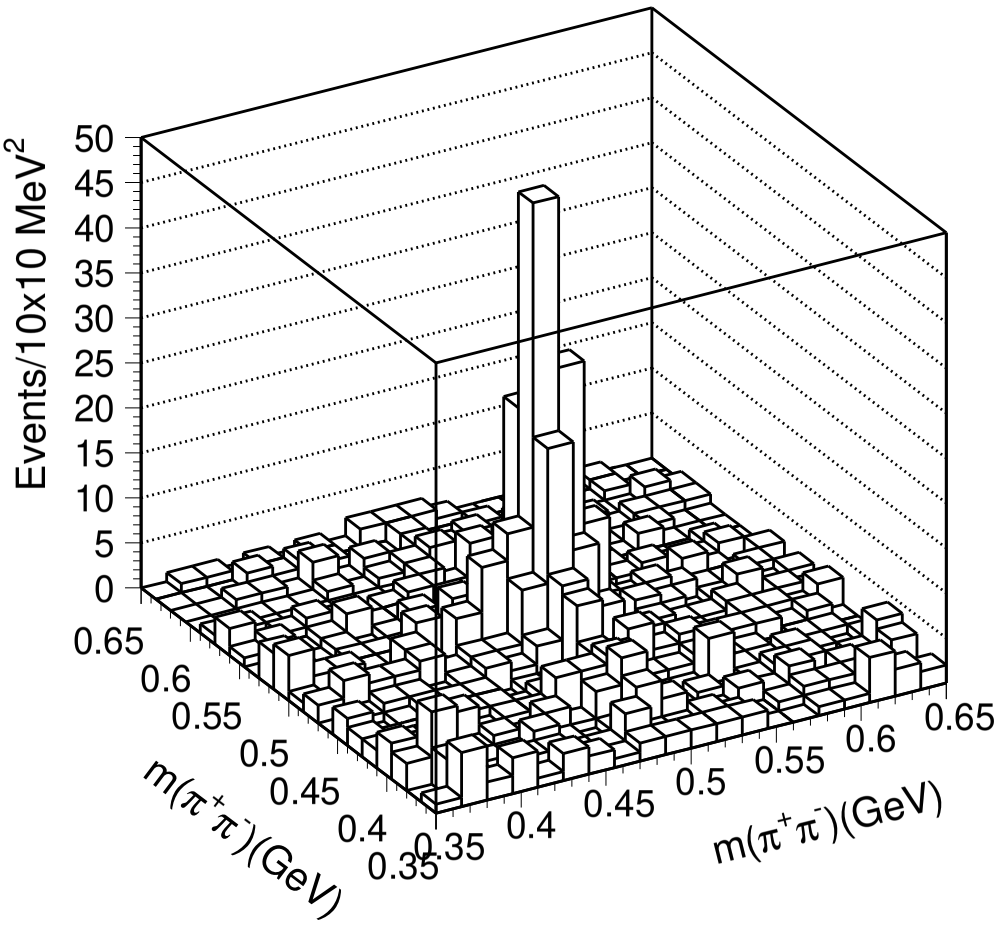
- Only $K^0_s \rightarrow \pi^+\pi^-$ decay is considered
- Search for secondary vertices in four "good" track events with charge balance
- $|\alpha| < 0.3$ rad
- $d_\perp > 3$ mm





To select $\gamma\gamma \rightarrow K^0_s K^0_s$ exclusive events :

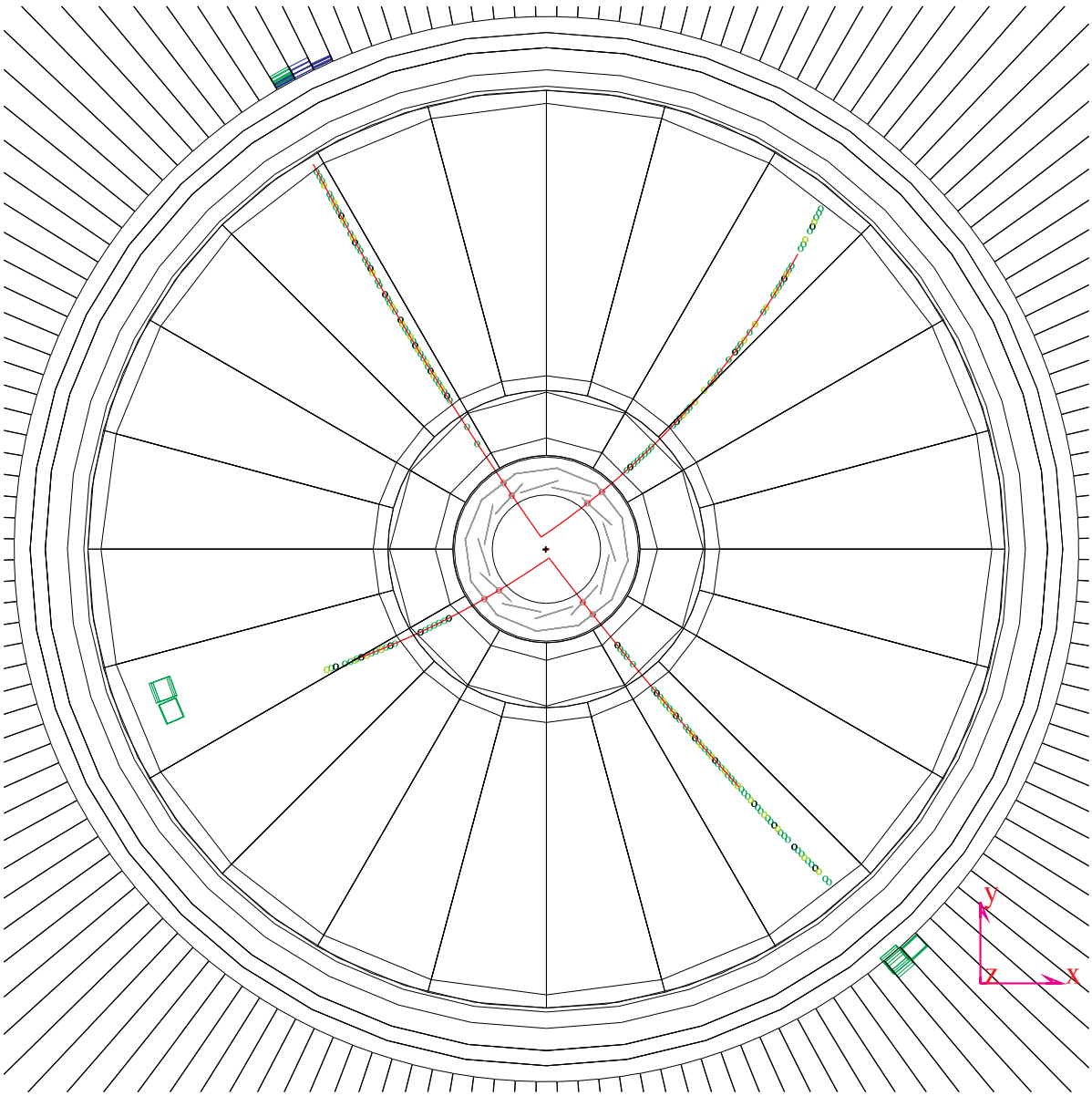
- $|\Sigma \vec{p}_T|^2$ <0.1 GeV^2
- Events with photons are rejected



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

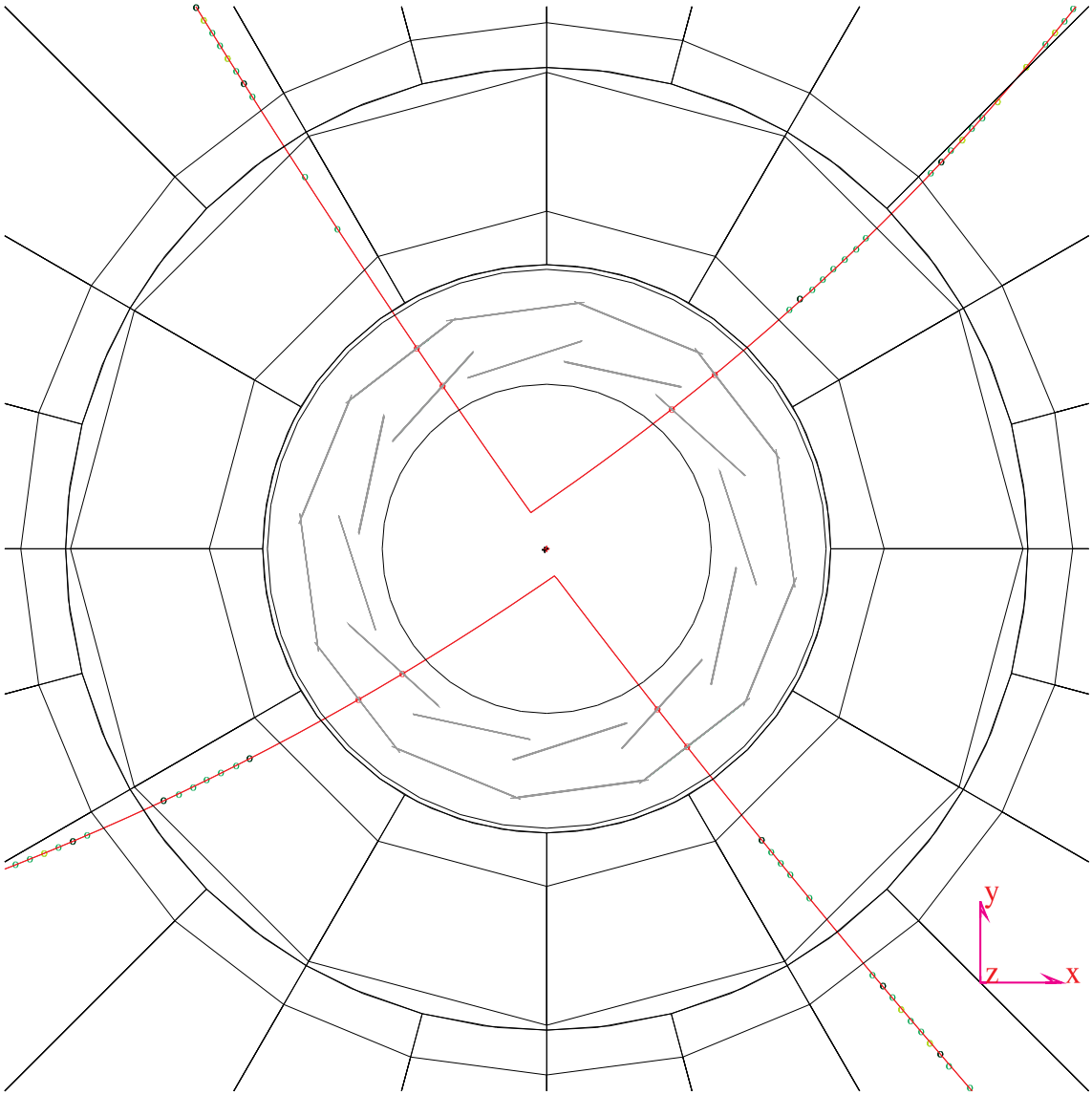
A $\gamma\gamma \rightarrow K^0_s K^0_s$ Event

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

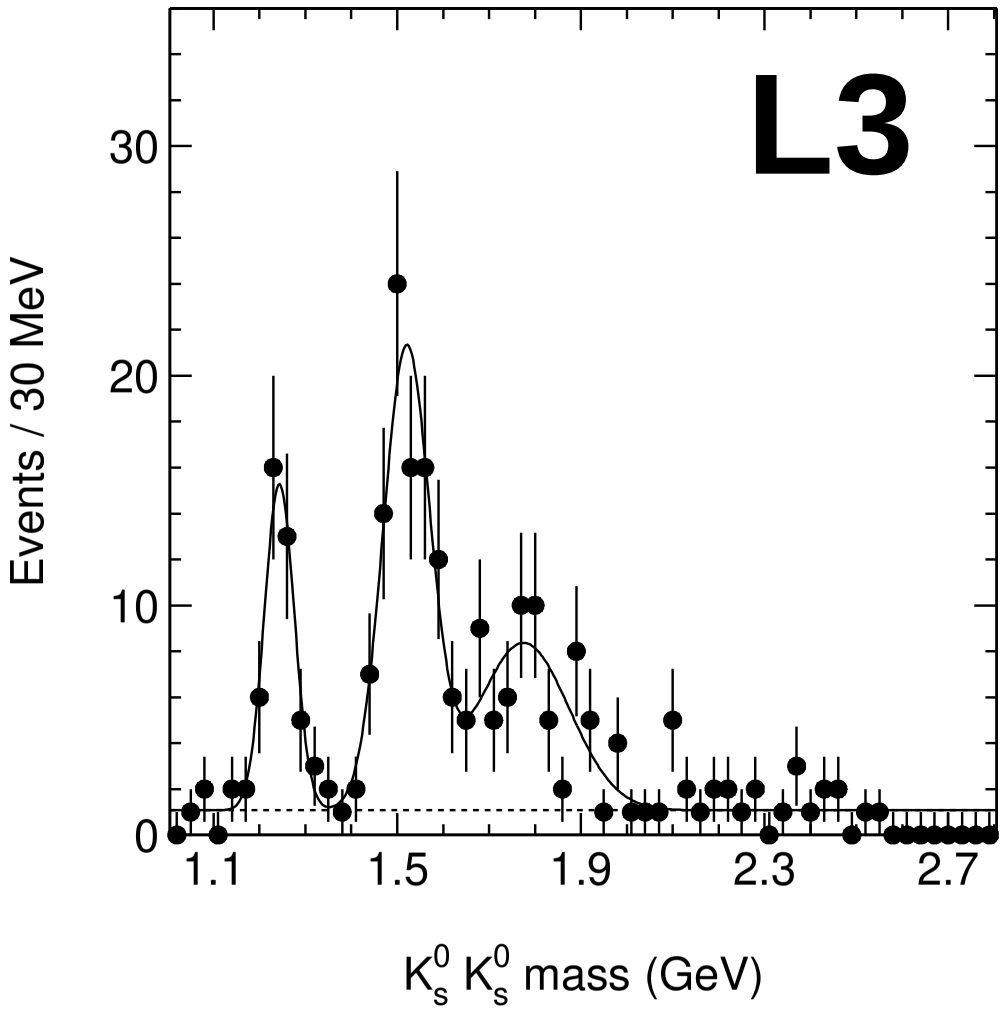


A $\gamma\gamma \rightarrow K^0_s K^0_s$ Event

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



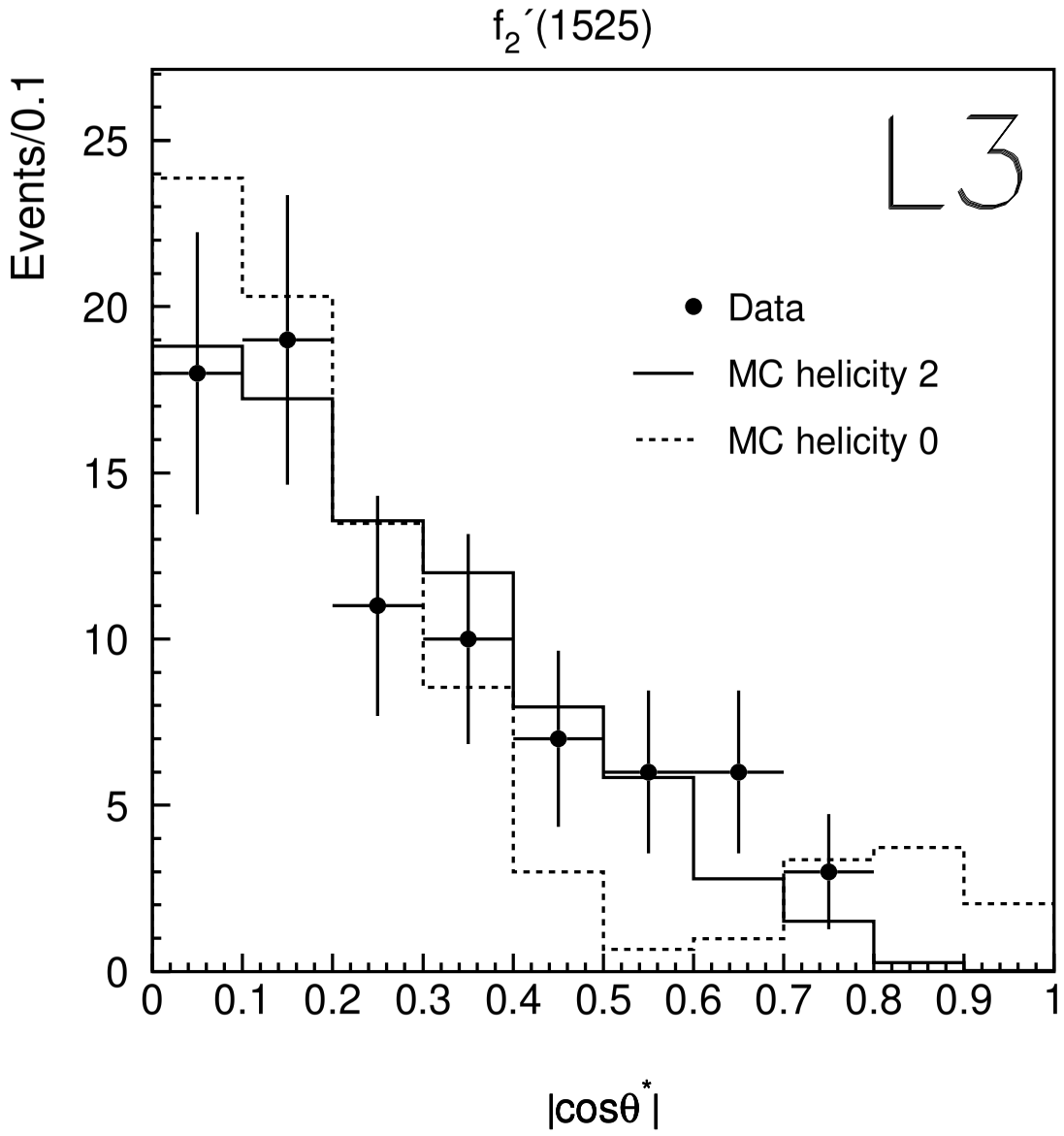
The $K^0_s K^0_s$ Mass Spectrum



	f_2-a_2	$f_2'(1525)$	1750 MeV
Mass (MeV)	—	1520±7	1770±20
Width (MeV)	—	119±15	200±50
Events	38±7	85±11	61±10

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

The $f_2'(1525)$



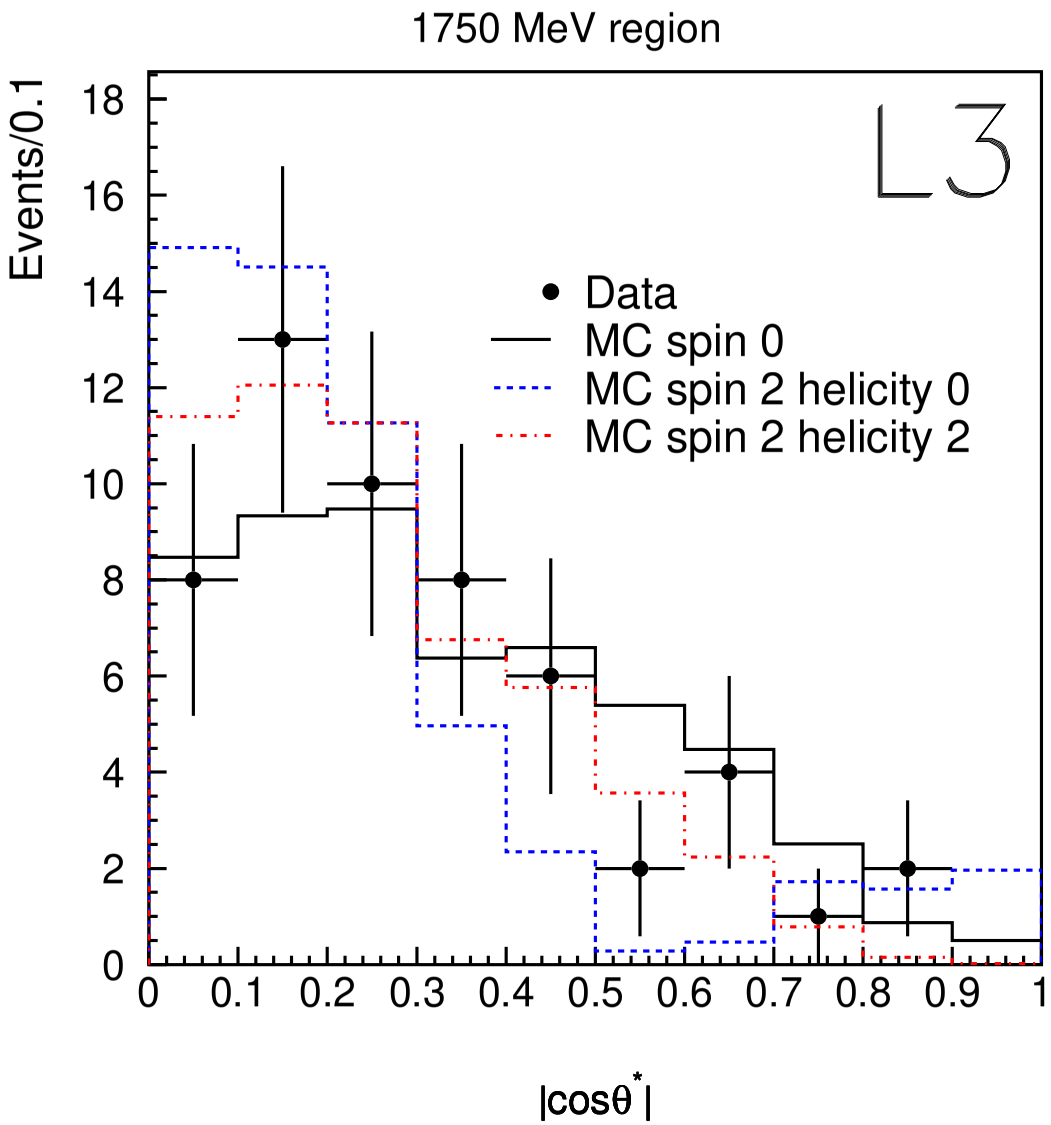
	J=2, λ=2	J=2, λ=0
χ^2 for 9 d.o.f.	7	82

Helicity 2 dominates !

For helicity 2 the detection efficiency is 7.6% and

$$\Gamma_{\gamma\gamma}(f_2') \times Br(f_2' \to K\bar{K}) = (0.085 \pm 0.03)\text{keV}$$

- $f_2'(1525)$ radial recurrence? $f_2''(1740)$, $f_2'''(1820)$
  (C.R.Münz, Nucl.Phys. A609(1996)634)
- 0^{++} $s\bar{s}$ state ? (C.Amsler and F.E.Close)



	J=0	J=2, λ=2	J=2, λ=0
χ^2 for 9 d.o.f.	7	26	50

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	2	7.9	9.3%	3.6	6.9 eV

Combining the two results by Monte Carlo :

$$\boldsymbol{\Gamma_{\gamma\gamma}(\xi) \times Br(\xi \rightarrow K^0_sK^0_s) < 3} \text{ eV at 95\% C.L.}$$

Stickiness

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

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

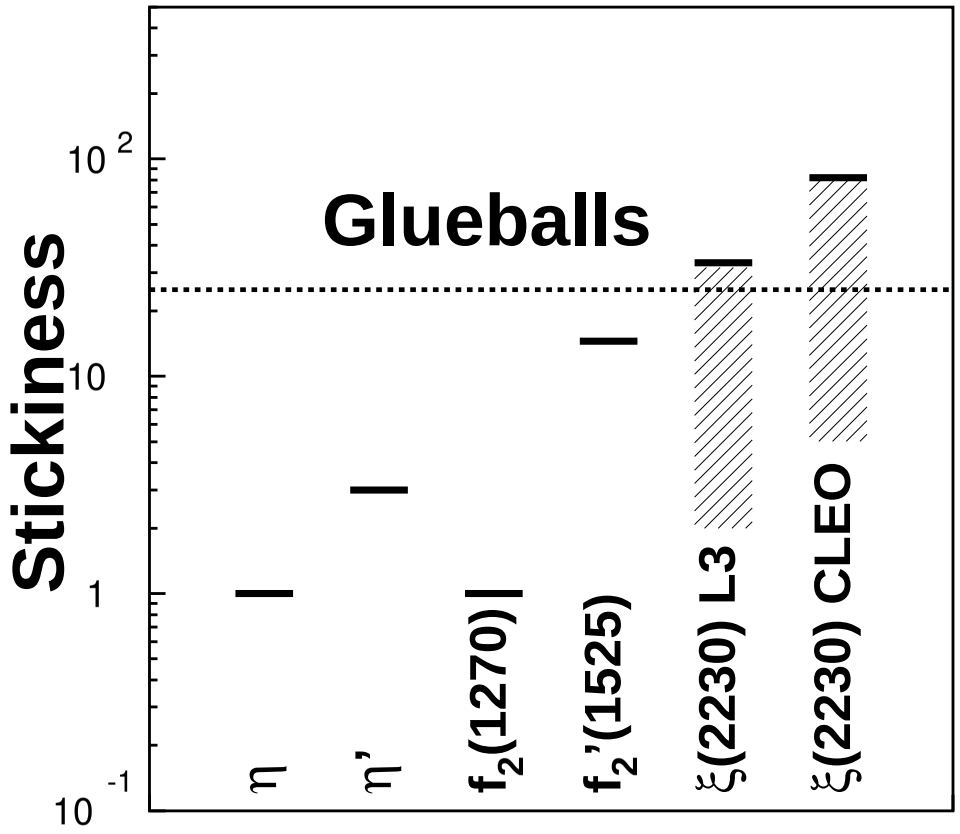
where:

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
$\Gamma(\xi \to \gamma\gamma)Br(\xi \to K^0_s K^0_s)$ <3 eV at 95% C.L.
we obtain

$$S_\xi > 33.3 \text{ at } 95\% \text{ C.L.}$$

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 $\xi(2230)$ ia a good glueball candidate, according to lattice QCD theoretical predictions.

Conclusions & Outlook

- The $K^0_s K^0_s$ final state is dominated by the formation of the $f'_2(1525)$ tensor meson in helicity 2 state
- $f_2 - a_2$ destructive interference
- 60 events in the 1750 MeV region: radial recurrence of the $f'_2(1525)$? 0^{++} $s\bar{s}$ state?
- No signal for the $\xi(2230)$:
  $\Gamma(\xi \to \gamma\gamma) Br(\xi \to K^0_s K^0_s)$ <3 eV at 95% C.L.
  $S_\xi >$ 33.3 at 95% C.L.
- More data from LEP II are expected, taking data up to the year 2000. They will bring a significant contribution to glueball searches.