The $\eta_c(2980)$ formation in two-photon collisions

A. Oblakowska-Mucha, B. Muryn, G.Polok
T. Szumlak

DELPHI Collaboration

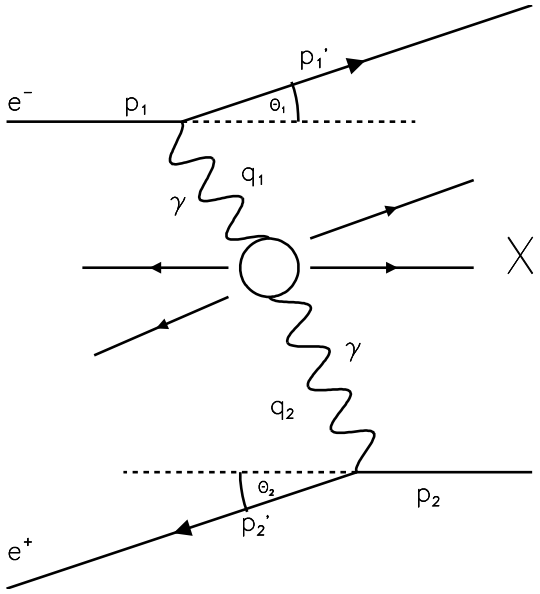
Faculty of Physics and Nuclear Techniques
University of Mininig and Metallurgy

Cracow

OUTLINE

- ▷ Two-photon Collisions
- ▷ Charmonium spectroscopy
- ▷ Data Selection
- ▷ Radiative width

Two-photon Collisions



- $W^2\gamma\gamma = (q_1 + q_2)^2$
- boost along the beam line
- θ_i small - untagged events

Exclusive resonance production

$$\sigma(e^+e^- \to e^+e^-\gamma\gamma \to e^+e^-R) = \int \mathcal{L}_{\gamma\gamma}\ \sigma(\gamma\gamma \to R)dW$$

$$N_{ev} \sim \mathcal{L}_{e^+e^-} \cdot \mathcal{L}_{\gamma\gamma}$$

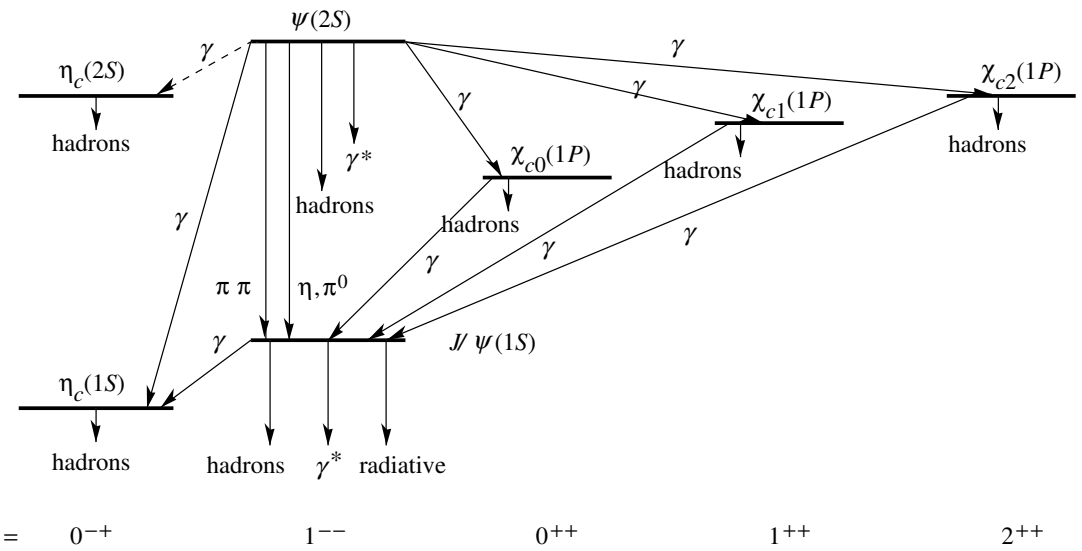
Selection rules

- C=+1, Q=0
- For quasi real photons - J=0,2

Radiative width (J=0)

$$\sigma(\gamma\gamma \to R) = 8\pi(2J+1)\frac{\Gamma_{\gamma\gamma}\ \Gamma_{tot}}{(W^2 - M_R^2)^2 + M_R^2\Gamma_{tot}^2}$$

Charmonium spectroscopy



Theoretical assumptions

◇ Bound states of $c\bar{c}$ are treated in frame of perturbative theory.

◇ Non-relativistic potential models successfully described and predicted many properties of the $c\bar{c}$ system.

◇ Radiative decay width with first (or higher) order QCD corrections.

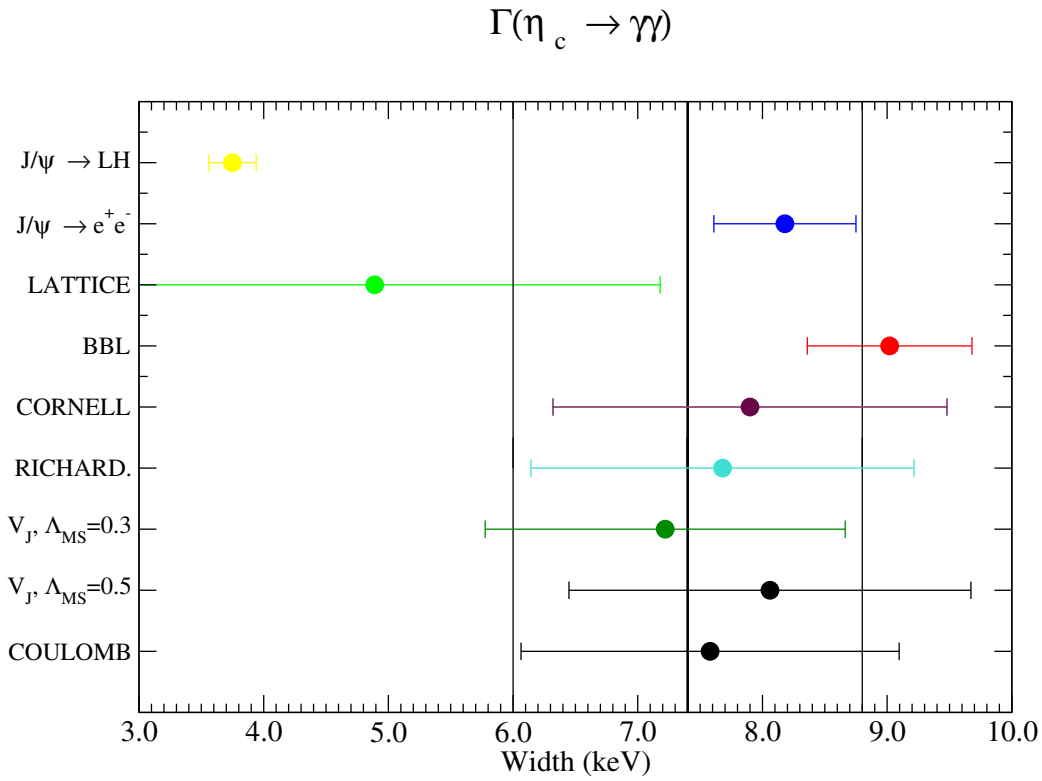
◇ Relativistic corrections.

$\Gamma_{\gamma\gamma}(\eta_c)$=3-11 keV

Estimation for the two-photon width $\Gamma_{\gamma\gamma}(\eta_c)$

◇ Recent calculation by N. Fabiano (hep-ph/0204214):

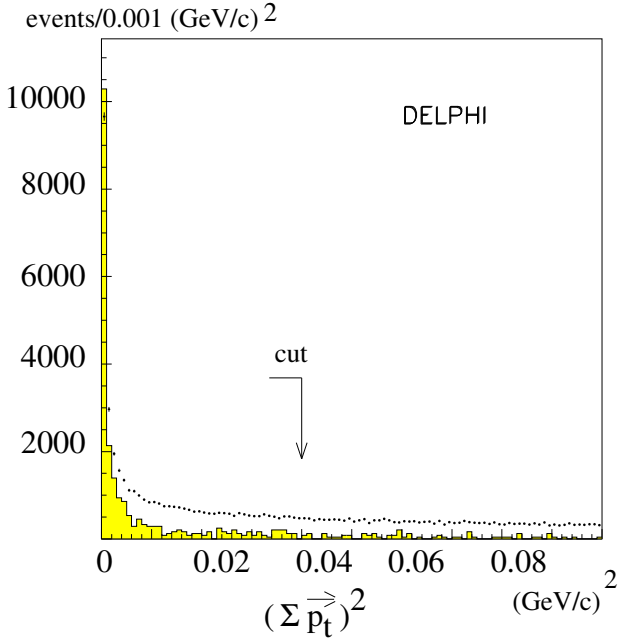
higher J/Ψ leptonic width, dependence of α_s on m_c scale, BBL (Bodwin, Braaten, Lepage) model:



Data Selection

$\eta_c(2980) \rightarrow$	$\mathcal{L}$ $[pb^{-1}]$	$\sqrt{s}$ [GeV]
$K^0_s K\pi$	73	90
$K^+K^-K^+K^-$	5.9	130-136
$K^+K^-\pi^+\pi^-$	20.1	161-172
$\pi^+\pi^-\pi^+\pi^-$	51	184
	153	189
	228	192-204
	$\int Ldt$=531 pb^{-1}	

- four charged tracks with zero total charge,
- total transverse momentum squared of charged tracks $(\Sigma p_t)^2 < 0.04$ (GeV)^2,
- total energy of charged tracks $E_{tot} < 10$ GeV,
- track quality cuts.



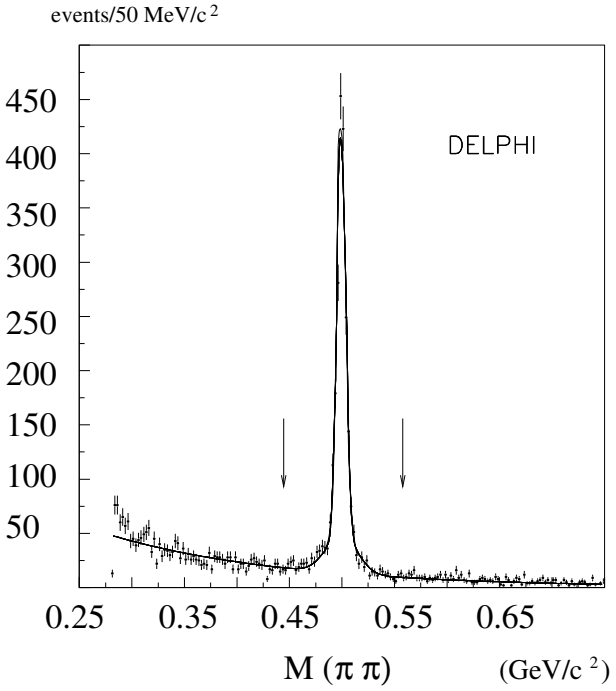
$\eta_c(2980) \to K^0_S K^{\pm}\pi^{\mp}$

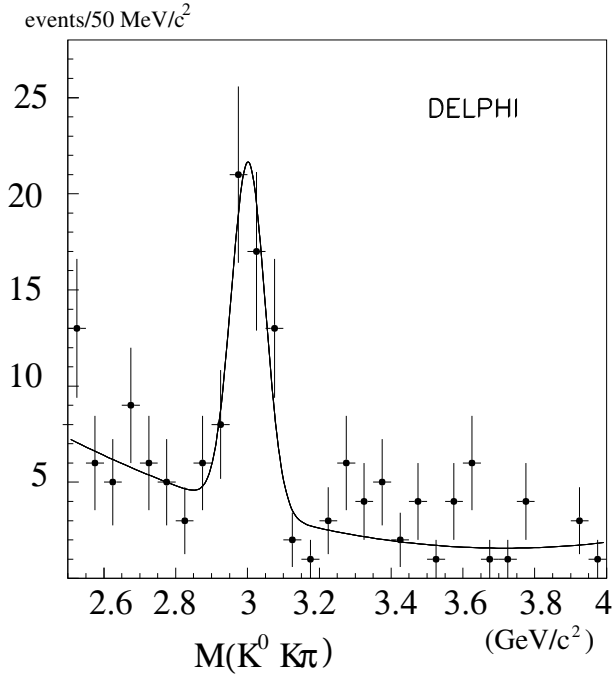
◇ search for secondary vertex

◇ mass of two pions around K^0_s nominal mass ($\pm$ 50 MeV),

◇ charged kaon identification based on dE/dx

energy losses.

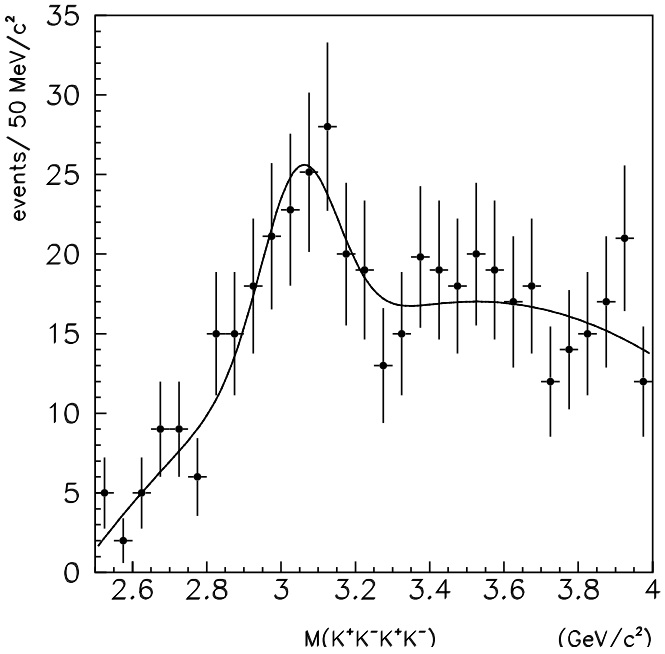




41 η_c events

$\eta_c(2980) \to 2(K^+K^-)$

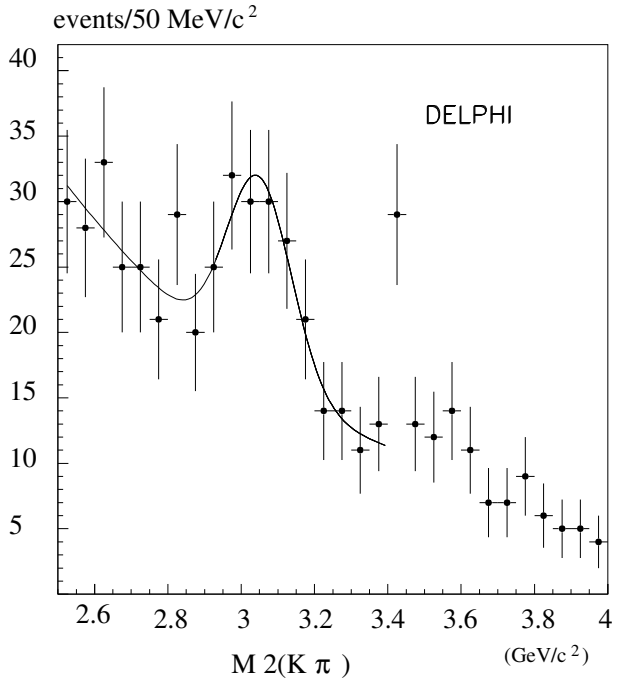
◇ at least three identified kaons (dE/dx)



42 η_c events

$\eta_c(2980) \to K^+K^-\pi^+\pi^-$

◇ identification of two pions and one kaon



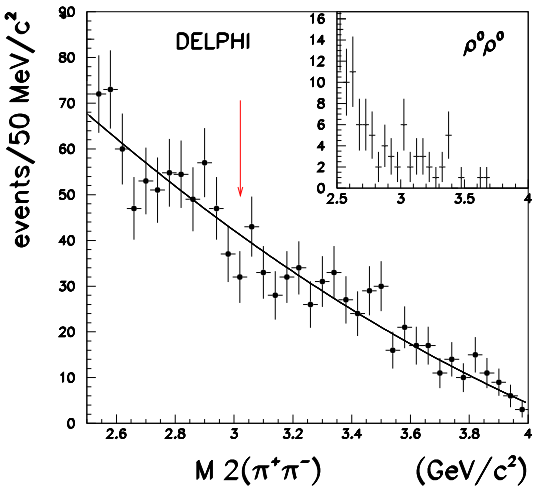
46 η_c events

$\eta_c(2980) \to \pi^+\pi^-\pi^+\pi^-$

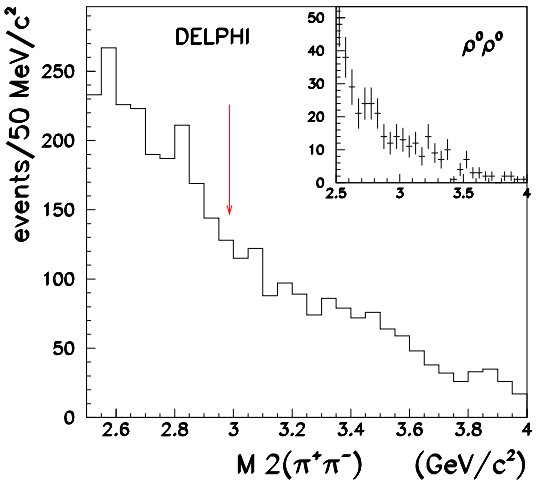
$\eta_c(2980) \to \rho^0\rho^0 \to \pi^+\pi^-\pi^+\pi^-$

◇ four pions identified

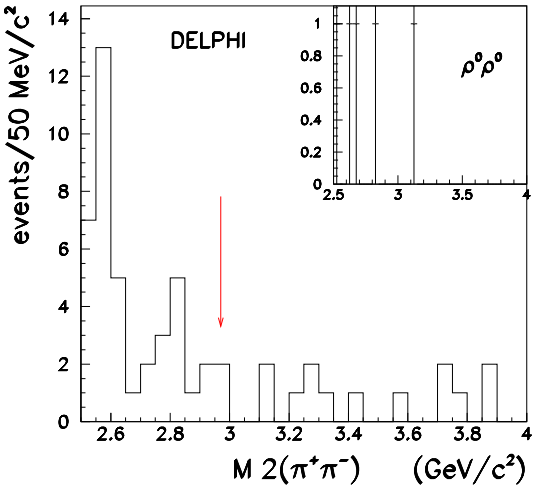
◇ ρ^0: $m(\pi^+\pi^-) = m(\rho^0) \pm 150$ MeV/c^2.



◇ loose 3π id:



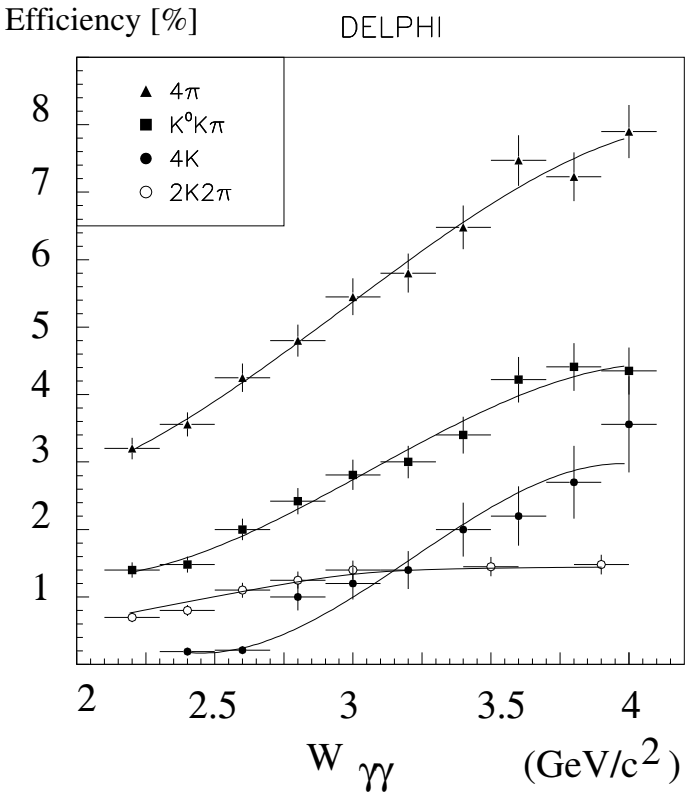
◇ tight 4π id, $(\Sigma p_t)^2 < 0.001$ (GeV)^2



Radiative width

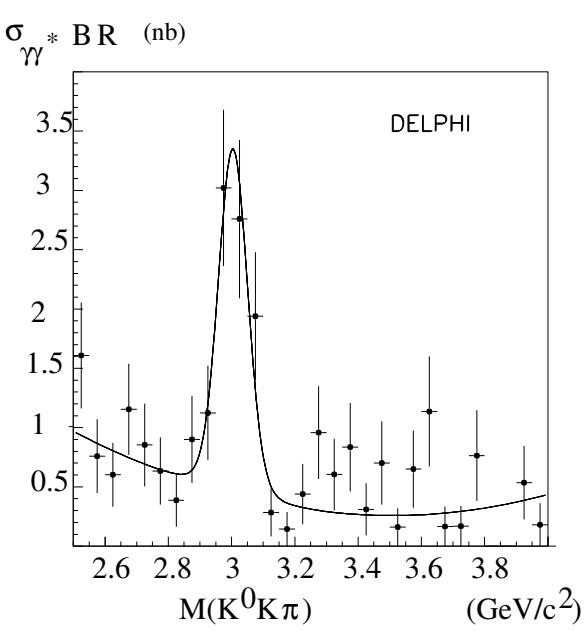
$\Gamma_{\gamma\gamma}(\eta_c)$ can be determined from two-photon cross-section

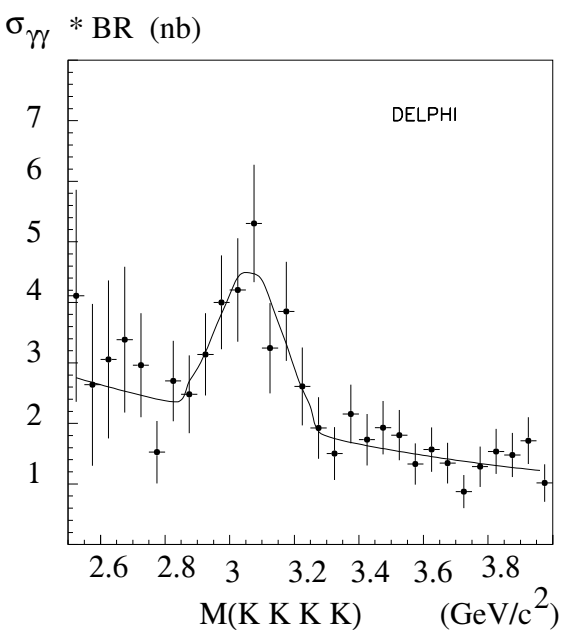
$$\sigma^i_{\gamma\gamma} \cdot BR = \frac{N_i}{\mathcal{F}_i \cdot \mathcal{E}_i \cdot L \cdot \Delta W_{\gamma\gamma}}$$

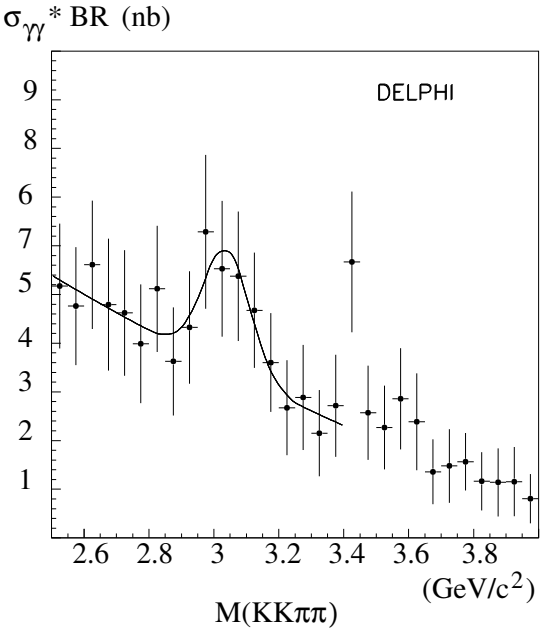


X	BR [%]
$K^0_s K^{\pm}\pi^{\mp}$	1.5 ± 0.4
$2(K^+K^-)$	2.1 ± 1.2
$2(K^{\pm}\pi^{\mp})$	2.0 ± 0.7

Two-photon cross section







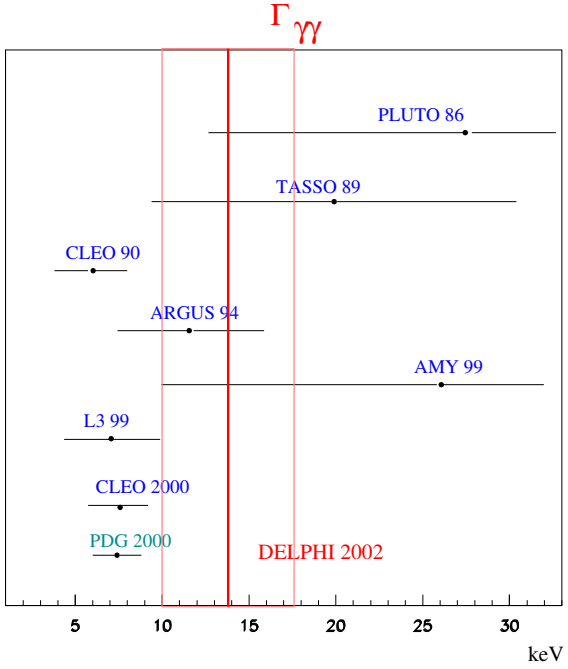
$\eta_c \to X$	$\Gamma_{\gamma\gamma}\cdot$ BR(X) [keV]
$K^0_s K^{\pm}\pi^{\mp}$	$0.198 \pm 0.038(stat.) \pm 0.030(syst.)$
$K^+K^-K^+K^-$	$0.346 \pm 0.090(stat.) \pm 0.057(syst.)$
$K^+K^-\pi^+\pi^-$	$0.283 \pm 0.095(stat.) \pm 0.059(syst.)$

Radiative width - other experiments

	$\Gamma_{\gamma\gamma}$ [keV]			
	final state			
experiment	$K_s^0 K^{\pm}\pi^{\mp}$	$2(K^+K^-)$	$2(K^{\pm}\pi^{\mp})$	$2(\pi^+\pi^-)$
PLUTO(86)	28±15	-	-	-
TASSO(89)	19.3±7.5±7.7	-	<23	26.2±10.2
CLEO(90)	10.9±4.1±3.4	<4.7	<14.7	<9.6
ARGUS(94)	15.4±3.7±5.0	10.9±0.3±1.0	8.2±3.9±2.3	16.7±6.7±3.5
L3(99)	5.5±4.7	-	16±8	<36
AMY(99)	27±16±10	-	-	-
CLEO(00)	7.6±0.8±0.4	-	-	-
DELPHI(01)	13.3±2.6±2.0 ±3.5(BR)	16.5±4.3±2.7 ±9.4(BR)	14.2±4.9±2.9 ±4.9(BR)	< 3.8

DELPHI averaged

$\Gamma_{\gamma\gamma} = 13.9 \pm 2.0$ (stat.) ± 1.4 (syst.) ± 2.7 (BR) keV



Conclusions

◇ The gold channel $\eta_c \to K^0_s K^{\pm}\pi^{\mp}$ is observed.

◇ $\eta_c \to 2(K^{\pm}\pi^{\mp})$, $\eta_c \to 2(K^{\pm}K^{\mp})$ decay modes are confirmed.

◇ $\langle \Gamma_{\gamma\gamma} \rangle$ = 13.9±2.0(stat.)±1.4(syst.)±2.7(BR) keV

◇ The decay $\eta_c \to 2(\pi^{\pm}\pi^{\mp})$ is not observed.

◇ No observation of $c\bar{c}$ excited states.